THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

The One Hundred and Twenty-First General Meeting of the Institution of Petroleum Technologists was held at the House of the Royal Society of Arts on Tuesday, October 8th, 1929, Dr. A. E. Dunstan, President, occupying the Chair.

The President, at the opening of the meeting, announced that in future the names of candidates for membership, after classification, would be read out at two consecutive general meetings of the Institution and published in at least one issue of the Journal before the ballot lists were issued, so that the normal time for a candidate's application to go through would be three months instead of one month as previously.

He also reminded the members that nominations for Council must be in the Secretary's hands by January 31st, 1930.

He regretted to have the announce that on September 18th the first Honorary Editor of the Journal of the Institution, Mr. W. H. Dalton, died at the very ripe old age of eighty-one. An obituary notice and a photograph would appear in the October issue of the Journal, which he was sure would appeal greatly to those members whose period of membership went back to the days when Mr. Dalton's monthly editorials were something very well worth reading.

He desired to announce that on December 5th the Institution, together with the Oil Industries Club, was holding a social evening, consisting of a dance and a cabaret. It was proposed also on December 19th to revert to the custom which existed years ago of holding a Conversazione. Mr. Kewley had very kindly collected a few interesting films of the American oil industry which would be exhibited, and he personally appealed to any of the members who were in a position to do so to supply any apparatus which could be set up in the library of the Royal Society of Arts for demonstration purposes on that evening. Light refreshments would be provided at the Conversazione.

He also desired once more to commend the Benevolent Fund to the earnest attention of the members. He was glad to say that previous appeals had been successful, but it was necessary that everybody should "pull on the rope." It was desired to collect a good capital sum to commence with, and then to institute regular annual subscriptions to the fund. He hoped the members would support the Benevolent Fund to the utmost of their powers, because he was sure they would appreciate that they would thus be doing very good work.

The Secretary read the following list of candidates for election :—

Members.—Carl Franklin Braun, George Walter Furniss, Frank Goldstone, George Hunter, Maung Maung, Thomas Taylor McCreath, F. Georg Mueller, Ernest Arthur Satchell, Howard Theophilus Wright.

Transfer to Member.—Frank Leslie Garton.

Associate Members.—Samuel Charles Anderson, Emanuel Dawidson, Cornelius Antoninius Aloysius Travers Dorans, Arthur George Fenn, William Herbert Harris, Humphrey Harvey Martin, Ernest Patrick Pink, Alexander Reid, Charles Arthur Ross, Edward Kenneth Sargison, Philip Alfred Stiff, Leonard Arthur Toone, George Albert Edward Walling, Jack Watson, Lancelot James Wilson, Alfred Samuel Wolfner.

Transfers to Associate Members.—Oswald Augustine Bell, Neville Aspinall Clegg, Richard James Hayman, Donald Albert Howes, Kenneth Chesterton Johnson, Walter Beveridge Rowntree, Herbert Muggleton Stanley, Ernest George Thorn, George Scott Urquhart, Christopher John Ward, Leslie Newton White, Edward Flasby Whittingdale, Richard Llewelyn Wilson.

Student.—Wilfrid Herbert Parsons.

Associates.—Boris Dvorkovitz, Stanley George Green, William Deacon Jarvis, Donal Wheeler O'Brien, Tressilian Walter Ranson, William McKechnie Robson.

Transfer to Associate.—John William Weitz.

Drilling Conference in Paris.

Mr. Ashley Carter reported that, in accordance with the President's nomination, he attended the Second International Drilling Congress which had recently taken place in Paris. On the occasion of the First International Drilling Congress held in Bucharest four years ago a fair number of papers were presented, and could be seen in printed form in the Institution library. The Paris Congress opened on September 15th, 1929, with a formal inaugural session, the business meetings commencing on the following day. Those meetings were held in a house which was formerly occupied by the Rothschilds, consisting of a magnificent building containing two large salons which were placed at the disposal of the Congress, so that two meetings could be held simultaneously. From 250 to 300 delegates from all parts of Europe attended the Congress, including a few representatives from England, and one or two from America.

As a matter of fact, the American Government appointed an official delegate to attend the Congress. The sessions lasted from nine o'clock in the morning until mid-day, and from two till five in the afternoon, following which during the continuance of the Congress various receptions, banquets, and so on were held. Upwards of 55 papers were presented, most of which were read and discussed at the Congress. Unfortunately some of the papers were received too late to be printed, but he understood that arrangements had been made for their subsequent printing and circulation. Most of the papers were in French; there were a few in German, Italian and Polish; and seven were sent from this country. It was obvious that the Drilling Congress was making real headway compared with the first congress held four years ago. The papers read dealt not only with drilling in its various aspects, but also with geophysical and other subjects, including geology; but the papers were mainly confined to the subject of drilling. A committee sat twice during the Congress Meetings, and arrangements were made by it for the Third Congress to be held in Berlin in 1931. He particularly desired to acknowledge the wonderful hospitality that all the delegates received. They were made thoroughly welcome, and were treated with the utmost kindness. He trusted that more members of the Institution would be able to be present at the Third Congress in Berlin in 1931.

The following papers were then read:—

The Estimation of Gum in Petrol and its Significance.

By Lieut.-Col. S. J. M. Auld, O.B.E., M.C., D.Sc. (Member).

Looking back at the specifications generally adopted for motor fuels during the last ten or fifteen years, one sees that many of the standards have had little relationship to the actual requirements of the consumer and have often been set, rather arbitrarily, by the producer to meet the exigencies of his markets. The best known case of this has been the distillation test, wherein the end-point has been gradually raised, as more and more petrol was required for the world's automobiles, from 150° C. to around 200° C without adversely affecting engine performance. Even now there is a movement towards discarding this criterion altogether and depending on a volatility test only, and should petrol become scarce, it can be taken for granted that this would sooner or later be done. The same thing applies to the allowable use of natural gasoline and of cracked spirit, both of which, in the past, were not permissible in high-grade motor fuels, but now are usual concomitants of ordinary petrol, only the lower grades of which are "straight run." Similarly,

there has recently grown up a strong tendency to question the justification for retaining the existing standards of sulphur content of motor fuels, the high cost of refining petrol from sulphurous crude oils beyond a certain stage having no obvious counterpart in increased value of the product.

With the setting up of new standards and the critical examination of all specifications likely to affect the production or value of motor fuel of the type regarded as most suitable for modern engines, it is natural that the question of the gum content of petrol should be given some attention.

It has really only been since the liquid phase cracking processes have come into extended use that much consideration has been given to the gum content of petroleum motor spirit, although the coal tar industry has for some years been interested in the gum-forming properties of certain unsaturated constituents of motor benzole. With vapour-phase cracking once more becoming of great importance, because of the high anti-knock value of the petrol produced, the question of gum formation is of particular interest, since vapour-phase cracked spirit is very high in unsaturated content and the early vapour-phase products were notoriously prone to the deposition of gum. With the tremendous improvement of modern vapour-phase cracking, both as regards operation and refining of the product, it is important that ideas regarding gum content should be revised and that the significance of limited gum content of all motor fuels should be appreciated in relationship to engine performance.

It is well known that a high gum content in petrol acts harmfully on the internal-combustion engine in which it is employed. On the other hand, it is also well known that many petrols of apparently high gum content, as determined by certain methods, have no deleterious action; and it is a fact that many vapour-phase cracked spirits which answer to this description, by reason of their high solvent action, actually keep the engine and the petrol system in a cleaner condition than would otherwise be the case.

It is important, therefore, that no test of the gum content or of the gumming nature of a petrol should be applied which is not capable quantitatively of differentiating between these cases. Otherwise, as pointed out by Egloff, a real hardship may be inflicted on the oil industry. This would be particularly undesirable at a time when it is important that no unnecessary difficulty be placed in the way of obtaining fuels wholly from petroleum capable of efficient use in high-compression engines. Nevertheless, some test must be devised, and at any rate temporarily adopted, before it is possible in any way to correlate gum content or gumming tendency with actual engine performance.

For some time the copper dish test, originally adopted as a corrosion test, was largely used. This method is unsatisfactory. It is incapable of accurate reproduction and the copper acts catalytically in the production of gum during evaporation. It has been greatly criticised during recent years, particularly by American petroleum chemists, and the recent work of the technical staffs of the Standard Oil Company of Indiana, summed up in an important paper by Voorhees and Eisinger[1], and of the Pure Oil Company (Wagner)[2], has rendered it obsolescent if not obsolete.

As a result of work by Smith and Cooke[3], considerably antecedent to that mentioned, Cooke[4] described a test for evaporation in the absence of air, and this test gives concordant results as a measure of the gum content actually present at a given time. It is generally conceded that it is only pre-formed gum—*i.e.*, actual gum content and not gumming tendency or potential gum, which affects engine operation. This being the case no evaporation test, however conducted, can be regarded as a satisfactory indication of behaviour in the engine. The time factor in the engine is extremely small, and no appreciable amount of chemical reaction involving gum formation can be expected to take place either in the intake manifold or in the cylinder. This aspect of the case is also referred to by Leslie[5], who points out that since highly unsaturated hydrocarbons of the type responsible for gum formation are quite likely to be formed transiently in the cylinder under the conditions of combustion, there can be no objection, *per se*, to their presence in the motor fuel. That only pre-formed gum is of any importance in affecting the value of a petrol at the time of its introduction into the engine appears fully proved from the work of Voorhees and Eisinger (*loc. cit*) and is the consensus of published opinion of all who have worked on the subject. Hoffert and Claxton[6], working with motor benzole, state : " The resinified or partially resinified constituents already present in solution in the benzole before use are chiefly responsible for the troubles experienced when using these benzoles in an internal-combustion engine. Very little resinification of volatile unsaturated constituents takes place in the engine itself. It is previous resinification during storage, therefore, on which the gumming of the engine primarily depends."

It is only when the actual gum exceeds certain limits that trouble is experienced. Delimitation of gum content in vapour

[1] *American Petroleum Inst. Bull.*, 1929, 10, No. 2, 169.
[2] J. Inst. Petr. Techn., 1929, 15.
[3] Bur Mines, Report 2394, 1922.
[4] Bur Mines, Report 2682, 1925.
[5] Motor Fuels, p.
[6] Report of the Joint Committee of the National Benzole Association and the University of Leeds, 1929.

phase cracked spirit is readily attained by modern methods of production and refining, the practical result being the fact that many millions of gallons have been consumed by the American public during the last three years and that, at present, production cannot keep pace with demand.

Before being able to discuss the meaning of individual gum figures it is necessary to describe the method of estimation actually employed.

It has been developed by the chemists of the Pure Oil Company and adopted by the writer and his associates for works use as a modification of the procedure recommended by Smith and Cooke.

It is well known that gum forms in any motor fuel containing olefines when it is exposed to the action of oxygen. The rate at which the formation takes place is dependent upon the following factors: Time of exposure, concentration of oxygen in the atmosphere over the petrol, the percentage and kind of olefines present, the temperature of the liquid, the amount of agitation or the rate at which the surface exposed to the oxygen is changed, and the extent of access of actinic light or other catalysing influences. Any method for determining the preformed gum must either eliminate oxygen altogether (as Smith and Cooke have done) or render its effects negligible.

The simplified method used to meet these requirements as nearly as possible is as follows:—

Into a weighed specially made Pyrex glass evaporating dish of 30 c.c. capacity (Emil Greiner Co., New York) is pipetted 20 c.c. of the sample to be tested. The dish plus contents is placed on an actively boiling steam bath and kept there until evaporation appears to have ceased. The dish is then removed to an electric oven heated to 105° C. and kept there for half an hour. Finally, the dish is allowed to cool in a desiccator, weighed, and the weight difference reported as grammes gum per 20 c.c.

In the hands of an experienced operator this method yields fairly good checks, although a great deal depends on the rate of evaporation. Samples containing smaller amounts of gum appear to give better checks than those containing larger amounts. That gum determinations made in dishes is a relative matter is indicated by figures which show a progressive weight decrease when gum dishes are kept in the oven for longer periods of time.

A comparison of runs made in the steam oven (according to the method of Smith and Cooke) with those made on the steam bath shows that the latter values are always higher than the former.

From this result is to be concluded that some oxidation still takes place on the steam bath during evaporation. On the other

hand, the steam bath method is undeniably more simple and expeditious than the steam oven method. After long experience with the method it is considered that there is little to be gained by the use of the steam oven process as against the steam bath evaporation except in those cases where a large amount of gum is present, and this is a rare occurrence with finished petrol in modern practice.

The steam bath modification of the "glass dish" gum test is considered to be sufficiently accurate for most purposes, and certainly for comparative purposes and works control. It is rapid and definitive, requires no special apparatus other than the glass dishes, and demands no great amount of technical skill from the operator. The order of concordance of results may be gauged from the following table of arbitrarily chosen tests, ranging from low to very high gum content:—

TABLE I.

Sample No.	Operator.	First test. grs.	Second test. grs.	Third test. grs.
1	A	0.0003	0.0003	0.0005
2	A	0.0026	0.0027	0.0029
3	A	0.0070	0.0062	0.0058
4	B	0.0107	0.0105	0.0075
5	A	0.0092	0.0081	0.0106
6	A	0.0100	0.0095	0.0103
7	A	0.0262	0.0263	0.0300
8	C	0.1328	0.1551	0.1288
9	A	0.1944	0.2227	0.2358

Change in the weight of the residues in the oven is inconsiderable during the time occupied by a test, but prolonged heating results in appreciable reduction of weight, pointing to the existence of volatile gum or to further resinification with separation of volatile products.

The following tests were carried out over a period of several days, weighings being made at irregular intervals:—

TABLE 2.

Sample	1	2	3	4
	0.0378	0.0241	0.0266	0.0314
Grs. gum	0.0262	0.0241	0.0241	0.0281
	0.0222	0.0228	0.0204	0.0262
			0.0184	0.0236
			0.0178	0.0220

As previously mentioned, the results are considerably higher than those from the steam oven method. Table III. shows this clearly, the results being two and a-half to five times as high, but being closely comparative for all but the lowest gum contents :—

TABLE 3.

Sample	1	2	3	4
Smith & Cooke's method	0.0002	0.0010	0.0036	0.0122
	0.0004	0.0009	0.0031	0.0112
	0.0004	0.0008	0.0031	0.0109
Steam Bath method ..	0.0011	0.0037	0.0219	0.0787
	0.0008	0.0032	0.0184	0.0636
	0.0007	0.0040	0.0170	0.0545

The copper dish method, as described in Bur. Mines, method 530. 1, Technical Paper 323-B, gives disproportionately high results. This is doubtless due to some extent to increased oxidation resulting from the longer time necessary to evaporate 100 c.c. over that needed to evaporate 20 c.c., but gum formation is unquestionably chiefly accelerated by the catalytic action of the copper dish.[1] As indicated by Table IV., the copper dish tests may be anything from six to sixty times as high as by the glass dish steam bath tests, and proportionately higher than those by Smith and Cooke's method :—

TABLE 4.

Sample	1	2	3
Copper dish (100 c.c.) ..	0.0954	0.1808	0.6277
		0.1930	0.9211
		0.20280	0.7309
Glass dish Steam Bath (20 c.c.)	—	—	0.1159
		0.0005	0.1205
	0.0038	0.0006	0.1284

It may be asked why, in face of the lower results given by the steam oven method, recourse has been had to the steam bath procedure. The answer is because of simplicity of operation and reasonable concordance of results, and because comparative values only are of use, as it is believed that no evaporation method even in the absence of oxygen and in the dark is really satisfactory as a measure of pre-formed gum. As long as it is realised that the figures are much higher than *can* be obtained the simple test is of great value.

[1] cf.

If a test were to be made to show the least quantity of pre-formed gum it would best be carried out on a minimum quantity of liquid evaporated at a more elevated temperature and using dishes of inert material of high thermal conductivity, possibly gold or platinum, and with the final heating of the residue also carried out in total absence of oxygen, since the gum itself can take up oxygen and increase in weight in the early stages of heating (Cf. sup.). Such conditions would, undoubtedly, limit the amount of gum formed during the evaporation test. That this is considerable is seen from the variation of results given by even comparatively slight modifications of the evaporation method. In this connection the experience of the author and his associates is not in accord with the views of Hoffert and Claxton[1] who consider that there is no formation of resin during the evaporation of motor benzoles.

Engine Operation.

The "acid test" of the significance of gum content in motor fuel is engine performance. Since only pre-formed gum has any bearing thereon the vital point is the correlation of gum content and engine operation for the purpose of delimiting the former, leaving questions of stability or potential gum formation to separate consideration. It should also be made clear that this correlation should apply in the meantime only to particular kinds of fuel, since the nature of the gums and, more important, their solubilities in various hydrocarbons or other motor fuel constituents, is not clearly defined. It is apparent that gum is less likely to deposit in the petrol or induction systems from fuels of higher solvent power than from those of lower. Results obtained with one class of fuel are not, therefore, necessarily applicable to other classes. Voorhees and Eisinger[2] for example, in their engine tests show wide variation in the deposit in the inlet passage between fuels of similar gum content, according to their source. The author's own observations have been chiefly concerned with the case of vapour phase cracked spirit.

Modern vapour phase spirit is gum-free when first made and develops gum content very slowly. It has been subjected to innumerable road tests and many millions of gallons have been consumed in all kinds of cars during the last few years. There is no question of bad effects resulting in the normal circumstances of storage and use. A five months old "Gyro Process" spirit on which the author is now making a road test contains less than

[1] loc. cit. 1928 and 1929.

[2] loc. cit.

one milligram of gum. As a conservative and somewhat arbitrary standard, a limit of gum content has been set by the principal producers of vapour phase spirit of 5 mg. as determined by the steam bath method and it is interesting to note that this corresponds closely to the limit tentatively suggested by Voorhees and Eisinger, of 10 mg. per 100 c.c. for the steam oven method. Trouble of any kind only begins to make its appearance when the gum content exceeds 10 mg. by the steam bath method and in practice ninety per cent. even of such cases have occurred because of the solvent action of the vapour phase spirit on gum, etc., already present in the tanks and petrol lines of the engines concerned. In making any tests, it is, therefore, necessary to clean the whole of the petrol system with a few gallons of the vapour phase fuel beforehand.

The most interesting tests are those now being made with vapour phase cracked spirit of deliberately high gum content, in order, if possible, to determine the upper limits of gum permissible, in any circumstances, in marketable fuel.

The following tests, chosen from many others of a similar nature, are indicative of the results obtained up to the present. They were carried out on a model "T" Ford engine, the materials used being as follows:—

A. A "Navy" specification spirit, off colour and of high gum content:—

S.G.	—	0.7830
Colour	—	+10 Saybolt.
I.B.P.	—	42°C.
E.P.	—	229°C.
Gum	—	0.0120/20 c.c.

B. A refinery once-run end-point distillate:—

S.G.	—	0.7752
Colour	—	+11 Saybolt.
I.B.P.	—	41°C.
E.P.	—	228°C.
Gum	—	0.0190/20 c.c.

C. A finished "Gyro Process" Spirit stored under oxygen for some time to increase the gum content:—

S.G.	—	0.7479
Colour	—	+30 Saybolt
I.B.P.	—	29°C
E.P.	—	214°C
Gum	—	0.0146/20 c.c.

The engine was run under varying load. Test "C" was run under a load of 10 h.p. and with a water temperature of approximately 180° F.

TABLE 5.

Motor Fuel.	Duration of test. Hours.	Spirit used. Galls.	Remarks.
A	258	241	Engine in good condition at the end. No gum in petrol system. Some deposit around inlet valves, but no sticking. Carbon in cylinders no more than average and soft and fluffy instead of the hard coating usually found.
B	128	76	Heavy carbon deposit in cylinders and some gum in carburettor. Sufficient gum on valve stems to interfere with efficient operation.
C	70 (with two shut downs of 3 hours.)	96	Engine in good condition throughout. No gum in the carburettor and only traces around the valves. Very little carbon in cylinder head.

It is not wished to draw hard-and-fast conclusions from tests of this character, but it is significant that the runs, of quite considerable length, with spirit (A and C) which originally started off gum-free at the refinery and then accumulated gum during storage or by contamination, or factitiously by oxidation, are proportionately much better than that with a not fully refined spirit. (B.)

It is probable that the gums in the two cases are different in nature, and that those from the gum-forming compounds removed during refining are the more obstreperous. If this is the case, it would point to still further need for modification of the gum test. This aspect of gum formation is being further examined, as it may, obviously, profoundly affect all conclusions regarding the significance of gum content.

It is somewhat premature to suggest standardisation of engine tests. In the meantime, road tests, involving variation of load and speed of engine and periods of shut down, are more stringent and more satisfactory than bench tests.

Where bench tests are carried out, these should be made under conditions simulating road operation and with observation of water and induction manifold wall temperatures. The parts of the engine to be examined most carefully are (1) the petrol lines and carburettor, and (2) the induction system, inlet valves, seating and guides. The cylinder and the ignition are not of such importance. In this connection Voorhees and Eisinger[1] state: "The amount of deposit inside the cylinder head does not seem to be in any way connected with the gum content of the fuel used. The variation in this deposit from run to run is probably due to differences

[1] *loc. cit.*

in conditions." As pointed out by Hoffert and Claxton[1], gum actually passing to the combustion chamber is burnt. In the case of refined vapour phase cracked spirit, the carbon deposit from a properly burnt fuel is generally less troublesome than from other hydrocarbon fuels.

Potential Gum.

The tendency of a motor spirit to gum formation is, of course, an entirely different question from that of its gum content at any one time. A petrol may show a gum-free test to-day, but if by to-morrow it is full of gum, to-day's test has little meaning. In effect, a stability test must reproduce, or give results understandable in terms of, normal conditions of storage and use. Gumming is an oxidation phenomenon and accelerated by certain conditions, notably the presence of some catalysts, access of light and rise of temperature. Ordinary storage excludes all three considerations. Moreover, certain materials in contact with or dissolved in the motor fuel act as inhibitors of gum formation. The test must ignore all such artificial conditions and attempt to reproduce those encountered by the petrol during storage in bulk or in tin over a period likely to be experienced in practice.

The question is a ticklish one. Since there is, or should be, no question of measuring the ultimate total gum which can be made in any circumstances, the test must partake of the nature of a limited oxidation, and this limitation must be fixed to represent the condition of some definite period of storage, and this period must be fixed. In the meantime, owing to lack of information, the choice of these conditions must be arbitrary.

Oxidation as a test of stability has been suggested in turn by Hoffert and Claxton[2] and Voorhees and Eisinger.[3] The former use a method whereby oxygen at a definite rate is bubbled through the spirit (benzole) under observation. The second named approach the problem in a rather more fundamental manner.

It is now the general opinion of investigators in this field that the slow oxidation phenomenon of gumming is also a typical case of auto-oxidation such as is experienced by certain oxidisable bodies in the presence of others of similar nature capable of forming intermediate peroxides. In such phenomena there is a definite induction period. Corresponding to this there is, in the case of gumming, a long and distinct interval during which oxidation is very slow and relatively constant. On this basis Voorhees and

[1] *loc. cit.* 1929, p. 29.
[2] loc. cit., 1928.
[3] loc. cit.

Eisinger conclude that the resistance of a motor fuel to oxidation, and consequently gumming, can best be measured by the duration of the induction period. They, therefore, devised a procedure in which the spirit is enclosed in a flask, otherwise filled with oxygen, and the initial pressure maintained at 1.5 atm. gauge when the flask is surrounded by steam. The fall in pressure measures the extent and rate of oxidation and the induction period is readily observed. In application of the test five hours was selected as the time of heating, as it was found that petrols free from gum trouble when stored for a considerable period were not appreciably oxidised in this length of time. Even with these data available Voorhees and Eisinger are diffident in attempting to recommend a limit, but content themselves with stating that a gum giving less than 40 mg. per 100 c.c. after the oxidation test will not form enough gum on storage, for at least a year, to impair its value.

As a measure of stability the present author and his associates also use an oxygen test wherein the sample is enclosed in a bottle, half filled, from which care is taken to exclude dust and moisture. The air is then displaced with oxygen and the bottle tightly stoppered with a clean cork. The sample is placed in northern light and allowed to stand. At 24 hour intervals, 20 c.c. samples are removed for gum determination. Experience has shown that this method readily distinguishes between stable and unstable spirits, some materials like sample A (Table 5) remaining fairly gum free, whereas others, such as sample B, an unrefined product, accumulate gum at a very rapid rate.

TABLE 5.

	Sample.	
Hours	A	B
0	0.0009	0.0072
24	0.0018	0.0452
48	0.0026	0.0678
72	0.0030	0.1420
96	0.0038	0.1825
120	0.0033	0.2269
144	0.0039	0.2670
168	0.0048	0.3323
216	0.0061	0.4409
240	0.0069	0.5208

This method has proved useful for both research and works control practice, but in view of the difficulty of defining conditions and the uncertainty attached to the meaning of the test, it is not at present intended to put it forward as a measure of stability.

Gum estimation is extremely sensitive to minute traces of impurities. Moreover, a petrol of high end point invariably gives

more gum than one of low end point from the same stock, and though this may indicate accumulation of gum forming unsaturated compounds in the higher fractions, it may also indicate greater susceptibility to gum formation during the test owing to the longer period required for evaporation.

In the circumstances the author only cares to sum up his conclusions as follows:—

(1) Estimation of gum by any evaporation process is not really satisfactory. In the meantime, any evaporation process which gives concordant results with a minimum of gum formation during the test may be regarded as suitable, providing it can be correlated with the behaviour of the fuel in engine operation.

(2) A procedure is suggested for the purpose.

(3) It is not difficult to produce motor spirit of high unsaturated content, *e.g.*, a vapour phase cracked spirit, to give good engine performance without gum trouble.

(4) Gum content as ordinarily measured may be quite appreciable without affecting engine performance. A conservative limit can be placed to this gum content if the *modus operandi* of the test is agreed upon. This applies to pre-formed gum.

(5) It is not at present possible to recommend a test of gum stability for general use to meet all requirements. Such a test is needed owing to the wide variation of gum forming tendency, especially as regards properly and improperly prepared vapour phase products.

(6) Practical limits must be set to such a test in order that no undue hardship may be placed on the petroleum industry in its endeavour to provide high anti-knock fuel from its own resources.

The Deterioration of Cracked Spirits by Gumming.

By E. W. J. Mardles, D.Sc., F.I.C., and H. Moss, D.Sc., A.R.C.S., D.I.C.

The gumming of cracked spirits is essentially an oxidation process involving the initial formation of organic peroxides. The absorption of oxygen from the air by the liquid or vapours of cracked spirits can be followed by enclosing the fuel in a vessel attached to a manometer and observing the gradual fall of pressure.

The process of gumming is complex. It appears to be initiated by the primary formation of organic peroxides which, by decomposition, by polymerisation and by autoxidation cause the formation and separation of resinous material. Usually, when cracked spirits are allowed to stand with air, there is a period of induction when the rate of gumming is small; this is followed by more rapid gumming as the products of oxidation accumulate. In absence of air cracked spirits appear to undergo little or no change even when exposed to heat or to actinic light, the anti-knock properties and gum yield remaining almost unchanged.

The rate of deterioration of cracked spirits is increased by aeration, by rise in temperature, by the action of actinic light and by the presence of deleterious substances such as certain sulphur compounds and substances which readily become peroxidised. Gumming is inhibited to a greater or less extent by absence of aeration, by the addition of "anti-oxygens" such as phenol or thymol, and by the surfaces of soda lime, copper or iron gauzes, etc.

There is an interesting relationship between the mechanism of the inhibition of gumming and that of the inhibition of knocking in an engine. It has been shown by Professor H. L. Callendar[1] that knocking is induced by organic peroxides. The addition of small amounts of "anti-oxygens" such as lead tetraethyl, iron carbonyl, toluidine, etc., suppresses the initial formation of peroxides preventing at the beginning the chain of reactions leading to knocking. Similarly, in cracked spirits, the inhibition of initial peroxide formation results in a marked decrease in gumming.

Brooks[2] has pointed out that a very marked positive test for peroxides can be obtained in a refined commercial cracked spirit after exposure to air and sunlight for half an hour. He regarded the most important reaction in the gumming of olefine hydrocarbons to be the formation of organic peroxides. Aldehydes,

[1] *Engineering*, **121**, 475, 1926; **123**, 147, 1927.
[2] *J. Ind. Eng. Chem.*, **18**, No. 11, 1198, 1926.

organic acids, ketones, water, etc., which accumulate, are regarded as the decomposition and reaction products of the organic peroxides, the decomposition occurring, for example, according to the following equation :—

$$\rangle C=CH_2 + O_2 = \rangle \underset{\underset{O-O}{|}}{C-CH_2} = \rangle C=O + H\cdot CHO.$$

Brooks examined the suggestion that gumming is caused by the condensation products of aldehydes, probably formaldehyde, and concluded that although this might be a contributory cause, the main cause appeared to be by the action of organic peroxides through polymerisation, etc. He showed that gums, especially when fresh, contained substantial amounts of explosive organic peroxides. These results have been confirmed in the Air Ministry Laboratory, many residual gums decomposing violently on the water bath.

Smith and Cooke[1] showed that as much as 18 per cent. oxygen is present in gums. Brooks found that one sample of pale yellow resin, about six months old, contained 30 per cent. of material freely soluble in water, about 30 per cent. of neutral oil, consisting chiefly of aldehydes and ketones, and about 40 per cent. of resin acids soluble in 3 per cent. aqueous alkali.

A very light coloured viscous gum was obtained by incubating some vapour-phase spirit at 50° for three weeks. When this gum was steam distilled organic acids, aldehydes, etc., were found in the distillate together with a neutral oil and a small portion of a gummy material. The gum was soluble in hot water to the extent of about 35 per cent., and the remainder dissolved completely in dilute caustic soda solution forming a slightly turbid solution. Active oxygen was present in the gum.

As would be expected, the occurrence of organic peroxides in cracked spirit after storage results in loss of anti-knock properties.

A portion of the olefine hydrocarbons responsible for the higher anti-knock properties of cracked spirits is also destroyed by oxidation ; thus, when a fuel after deterioration is redistilled, the original anti-knock value is not obtained.

A contributory cause to the falling off in anti-knock value after storage of cracked spirits is the fouling of the engine interior with deposits which render the engine sensitive to knocking.

Engine experiments with cracked spirits after storage under various conditions.—Engine tests were carried out on a Delco engine with bouncing pin equipment in the standard manner by comparison with fuels of known H.U.C. ratio. Several cracked spirits and their blends were examined after storage under different con-

[1] Bur. Mines Repts., Investigations No. 2394, 1922, C.A. 16, 4332, 1922.

ditions of aeration, light and temperature. The results are given in tabular form—Tables 1-4—and included in the tables are the gum yields (copper dish method) and the amount of active oxygen (peroxides) calculated as amylene peroxide.

In Table 1 the results obtained for cracked spirits stored at ordinary temperatures are given.

TABLE 1.

Deterioration During Storage in Tins or Bottles (Partially Filled) at 15° C. (average). No Sunlight.

Description of fuel.	Period (days).	H.U.C.R. Before.	H.U.C.R. After.	Diff.	Gum yield (mgs./ 100 c.c.).	Peroxides % wgt.
Refined commercial cracked Spirit A ..	23	5·5	5·25	0·25	37	0·01
Ditto	51	5·5	5·2	0·3	40	0·02
Refined commercial cracked Spirit B ..	120	4·8	4·5	0·3	170	0·1
Ditto, with half volume of straight-run petrol	120	4·8	4·3	0·5	—	—
Refined vapour phase Spirit C, capped at 150°..	30	5·95	5·8	0·15	30	—
Spirit C, capped at 175°..	30	5·85	5·65	0·2	25	—
Commercial petrol containing a proportion of cracked spirit ..	270	5·4	4·8	0·6	750	0·13

It will be seen from Table 1 that a decrease of anti-knock value has occurred in all cases with cracked spirits at ordinary temperatures, even for as short a period as 23 days.

The gum yield, too, has far exceeded the allowable limit of about 20 mgs. per 100 c.cs.

The results depend to a considerable extent on the conditions of storage, for example, the amount of air space, material of container, etc. Some results illustrating this behaviour are given in Table 2.

TABLE 2.

Effect of Conditions of Incubation Tests with Refined Commercial Cracked Spirit A.

Conditions.	Period (days).	Temp. ° C.	H.U.C.R. Before.	H.U.C.R. After.	Diff.	Gum yield (mgs./ 100 c.c).	Peroxides % wgt.
In plain glass bottle (full)	40	55°	5·5	5·5	0	.22	0
Ditto (half full) ..	35	45°	5·5	4·8	0·7	350	0·05
Ditto (one-sixth full)	35	45°	5·5	4·55	0·95	1290	0·13
Tin (half full) ..	35	45°	5·5	4·85	0·65	270	0·06

Incubation of cracked spirits and some blends were carried out at higher temperatures in order to accelerate the rate of

gumming. The results are given in Table 3. The additions of benzene or straight run petrol in amounts up to equal volumes did not effect an improvement corresponding to the degree of dilution. The addition of small amounts of phenol either to cracked spirits or its blends with petrol or alcohol did, however, afford a considerable improvement, reducing the gum yield and partly preventing the fall in H.U.C. ratio. Usually, the samples of cracked spirit became discoloured and sour and actual precipitation of the gum had begun in many cases after a month's storage at 45° C.

TABLE 3.

Deterioration During Incubation at 45° or 55° C. in Glass or Tin Containers, One-half to One-third Full.

Fuel.	Period (days).	Temp. °C.	H.U.C.R. Before.	H.U.C.R. After.	H.U.C.R. Diff.	Gum yield (mgs./100 c.c.).	Peroxides % wgt.
Refined commercial Spirit A	35	45	5·5	4·8	0·7	350	0·15
Spirit A, capped at 175°	60	45	5·3	4·85	0·55	30	0·35
Spirit A + half vol. of straight-run petrol	45	45	5·3	4·65	0·65	320	0·03
Spirit A + equal vol. of straight-run petrol	45	45	5·15	4·85	0·3	200	0·05
Spirit A + quarter vol. of straight-run petrol	40	55	5·45	4·8	0·65	1250	0·05
Spirit A + phenol, 0·5 gram./100 c.c.	48	55	5·5	5·1	0·4	55	0
Ditto + equal vol. of straight-run petrol	48	55	5·4	5·25	0·15	25	0
Spirit A + fifth vol. of benzene ..	45	45	5·7	4·8	0·9	820	0·04
Spirit A + tenth vol. of benzene + tenth vol. of ethyl alcohol	28	55	5·8	5	0·8	30	0·05
Spirit A + twentieth vol. of ethyl alcohol + phenol, 0·5 g./100 c.c.	48	55	5·65	5·5	0·15	28	0
Spirit A + twentieth vol. of butyl alcohol	24	55	5·5	5·05	0·45	330	0.08
Spirit A + fortieth vol. of aniline ..	24	55	6·1	5·55	0·55	225	0
Spirit B, capped at 200°	30	45	4·9	4·55	0·35	135	0·2
Ditto, capped at 175°	30	45	5·1	4·4	0·7	305	0·07
Spirit C, capped at 150°	45	45	5·95	4·25	1·7	5800	0·4
Ditto, capped at 175°	45	45	5·85	4·5	1·25	4950	0·55
Ditto + tenth vol. of ethyl alcohol ..	32	45	6·0	5·0	1·0	1440	0·45
Ditto + equal vol. of straight-run spirit	32	45	5·3	4·35	0·95	1800	0·45
Ditto + twentieth vol. of ethyl alcohol	32	45	5·45	4·2	1·25	1750	0·33
Ditto + fourth vol. of benzene	32	45	5·7	4·35	1·35	1900	0·3

After deterioration, there was only a partial return to the original anti-knock quality after reconditioning by alkali wash and redistillation. This is shown in the case of a refined cracked spirit and a blend (Table 4).

TABLE 4.

Improvement of Deteriorated Fuel after Reconditioning.

Fuel.	Removed. Gum mgs./ 100 c.c.	Removed. Peroxides % wgt.	H.U.C.R. Before.	H.U.C.R. After.	H.U.C.R. Fresh fuel.
Spirit A	65	0·06	4·85	5·1	5·5
Spirit A + quarter vol. of straight-run spirit	65	0·05	4·8	4·95	5·45

The engine was run at small throttle and low r.p.m., with small amounts of fuel. It was warmed up on ordinary petrol and during the testing was run alternately on the sample under test and on a petrol-benzene mixture. With the cracked spirits and blends of Table 3 after deterioration it was found that the engine required cleaning after about 6 tests (in one case 4 tests), the consumption of spirit being less than 1500 c.cs. Gum was deposited on the back of the inlet valve, on the valve stem and over the surface of the adjacent inlet passages on which a hard black glaze was formed. Rough deposits were found on the cylinder head round the inlet valves, particularly on the narrow space between the valve and the cylinder wall. These deposits formed hot spots and led to abnormally heavy knocking and to pre-ignition. When the engine was stopped and allowed to cool after the sixth test, the gum on the inlet valve caused the valve stem to stick hard-fast. The total running time between a thorough cleaning of the engine and the deposition of gum liable to cause valve seizure on cooling was about 5 hours.

MEASUREMENT OF GUM YIELD AND GUMMING TENDENCY.

It is a matter of considerable importance to be able to determine in a simple and precise manner the amount of gum likely to remain from the evaporation of a given quantity of fuel, because in addition to the possibility of fouling the engine if the gum yield exceeds about 20 mgms. per 100 c.cs. it will have been seen from the engine results given that the amount of gumming is an index to the degree of deterioration and to the fall in anti-knock properties.

Various limits have been set to the amount of gum permissible in fuel. 30 mgs. per 100 c.cs. have been regarded by Dean (Bur. Mines, Tech. paper 214) as the limit, but some sales organizations impose on their refining department the limit of 15 mgs. (copper dish).

Objections have been raised to the adoption of the commonly used copper dish test, because it is said not to discriminate between gum already in the fuel and that formed during the test in which the catalytic surface of copper is present. Vorhees and Eisenger[1] also consider that there is lack of oxidation control, the more volatile fractions being exposed to atmospheric oxidation for a shorter time than heavier constituents so that with the copper dish test the results would vary with the boiling range of the fuel.

Experiments have been carried out with various fuels in order to compare results by different methods and by altering conditions of test.

These results tend to show that the copper or glass dish method as commonly used gives results, when the conditions are standardized, which compare favourably with those obtained by more elaborate methods requiring special apparatus and a longer duration of test. Results obtained by evaporation in steam are considered to be equivocal since the gum is not inert to steam. Hydrolytic cleavage and steam distillation can occur to a degree depending on the nature of the gum.

The effect of different dishes on the gum yield by the usual method was first investigated, using refined commercial cracked spirit A. The results are shown in Table 5.

TABLE 5.

Gum Yield Ascertained by Different Dishes of Size 7 c.m. Diameter. Duration of Test 1 Hour ; 25 c.cs. of Spirit Used.

Description.	Gum yield (mgs./100 c.cs.). (Average of 2 or 3 readings.)
Copper dish : highly polished by buffing	15
" " dull surface	16
" " cleaned with metal polish	15
Glass dish	11
Glazed porcelain dish	10
Platinum dish	17
Nickel	13
Lead (2 hours' evaporation)	19

(With aluminium foil and tin foil in glass dishes values about 20 were obtained. These high values and those for platinum and lead appeared to have been due to incomplete evaporation of the spirit between and below the surface of the foil or to the thickness of the dish.)

Results obtained by placing the dishes on different size holes on the lid of the water bath or by blowing a stream of air

[1] Amer. Pet. Inst. *Bulletin*, 10, No. 2, 169, 1929.

across the surface showed that evaporation at lower temperatures gave lower yields; thus, a 3½ in. copper dish placed on a 2¼ in. instead of a 3¼ in. opening gave a value of 13 instead of 15, whilst with the stream of air across the dish the values fell to 10 and 11.

The temperature of evaporation appears to be of major importance. This is shown in further experiments in which evaporations were carried out in a special apparatus using air and other gases at different temperatures. The composition of the gum is affected by rise of temperature. By the ordinary method a soft brown resin was usually obtained which was soluble in acetone but at higher temperatures the residue was hard, black and granular and was intractable to solvents.

The apparatus employed consisted of a brass container maintained at any required temperature by means of an oil bath of welded steel (Fig. 1).

Steam, air or inert gas was first pre-heated by passing it through the coil immersed in the oil. It was filtered through woolly asbestos and passed gently across the dish lowered into the pot by means of a holder. The dish rested on three points fixed to the base of the holder.

About 20 c.cs. of the fuel were evaporated by the stream of air or steam, etc., passing at the rate of about 25 litres per hour. The duration of test was about five hours.

The results are given below in tabular form :—

TABLE 6.

Experiments with a Blend of Cracked Spirit A and Straight-run Petrol (50% vol.) After Standing for Several Months.

Description.	Gum yield (mgs./100 c.c.).	Remarks.
Copper dish : air at 110°	41	
" " " 125°	43	
" " " 150°	45	Black, hard gum.
" " " 175°	46	" "
" " steam at 125°	44	
" " " 150°	40	
" " " 175°	45	
Glass dish : air at 125°	49	Hard deposit.
" " " 150°	52	
" " CO_2 at 150°	45	Some creeping observed.
" " coal gas at 150°	40	

Results Obtained by Evaporation in Air by the Ordinary Methods were :—

Description.	Gum yield after two hours (mgs./100 c.c.).
Glass dish	42 (average of three)
Copper dish	42 (" ")

The Gumming of Cracked Spirits.

APPARATUS USED FOR ESTIMATING GUM YIELD FROM CRACKED SPIRITS UNDER DIFFERENT CONDITIONS OF TEST.

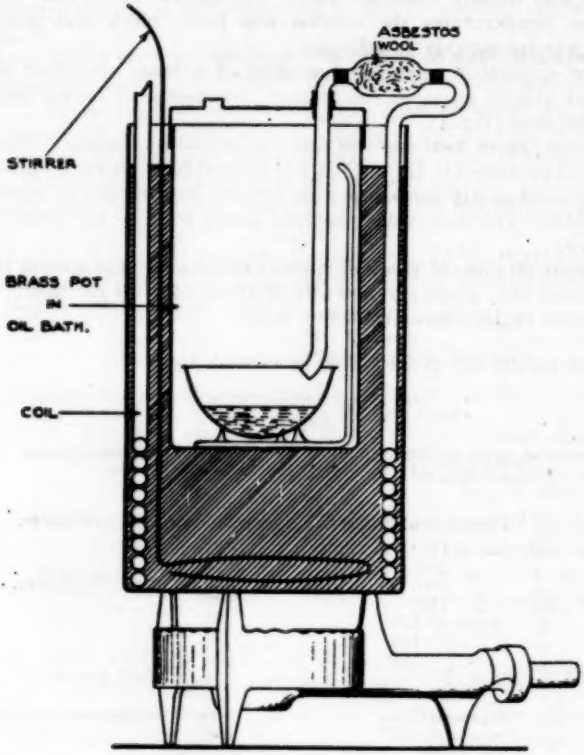


FIG. 1.

From the above results it will be seen that the ordinary method gives results after two hours which are comparable with those after five hours by the more elaborate method. With steam, oil was still present after two hours. The lowest results, viz. : 40, were obtained with superheated steam and coal gas at 150°. With rise in temperature, the gum yield increased slightly and the residue became black and hard.

Some difficulty was experienced in cleaning the copper dishes after use at higher temperatures and some pitting of the copper occurred. With glass these difficulties were avoided.

TABLE 7.

Experiments with a Blend of Cracked Spirit and Straight-run Petrol (50% vol.) After Standing for Several Months.

Description.	Gum yield (mgs./100 c.cs.).
Copper dish, air at 100°	57
„ „ „ 150°	60
„ „ steam at 150°	57
Glass dish, air at 100°	50

TABLE 8.

Experiments with a Cracked Spirit After Ageing for Twelve Months at Ordinary Temperature.

Copper dish, air at 150°	89
„ „ steam at 150°	75
Glass dish, coal gas at 150°	55

Results by Ordinary Method are :—

Description.	Gum yield (mgs./100 c.c.).
Copper dish	60 (average of three)
Glass dish	51 („ „)

From Tables 7 and 8 it will be seen that by the ordinary method, viz. : air at 100°, the results are relatively low, the copper dish giving the higher values. By the pot method, the lowest result was again obtained by means of coal gas.

TABLE 9.

Experiments with a Cracked Spirit Blended with Straight-run Petrol (50% vol.) After Incubation at 50° C.

Description.	Gum yield (mgs./100 c.c.). Two hours.	Three hours.	
Ordinary method copper dish	225 ..	225	
„ „ glass dish	325 ..	295	
„ „ lead dish	425 ..	350	
Air at 125° glass dish	— ..	385	hard deposit
„ „ copper dish	— ..	440	„ „
Steam at 125° copper dish	— ..	226	„ „

TABLE 10.

Results with a Cracked Spirit After Incubation at 50° for Several Months.

Description.	Gum yield (mgs./100 c.cs.). Two hours.	Three hours.	Four hours.
Copper dish in air at 100°	2908	2560	2380
,, ,, repeat	3025	2600	2425
Glass dish in air at 100°	3700	3220	2820
Copper dish in air at 125°	3640	3240	3120

Results given in Tables 9 and 10 obtained with fuels of high gum content show clearly the effect of the kind of dish on the duration of the test. With the copper dish, where conduction of heat is highest, the gum yield is lowest and is obtained more rapidly than with glass dishes. With fuels of high gum content, therefore, copper dishes appear preferable to glass or porcelain in order to reduce the time of the experiment.

Judging from experiments described later, copper does not induce gumming catalytically, and it is to be assumed that the higher gum yields sometimes obtained with copper dishes are due to the higher temperature of the dish caused by higher conduction of heat.

An interesting feature of some of the experiments with superheated steam was the gradual accumulation of water in the pot, although the temperature was several degrees above 100° C.

Influence of copper on gumming.—In the following experiments, a vapour phase cracked spirit was incubated at 35° C. for two months in the presence of different metals, etc.

Sufficient air was present above the spirit in the flasks to allow oxidation to occur freely. The following gum yields were obtained by the usual copper dish method :—

TABLE 11.

The Gum Yields of a Vapour Phase Cracked Spirit after Incubation at 35° C. in the Presence of Metal Foils, etc.

Description.	Gum yield (mgs./100 c.cs.).	Remarks.
Plain spirit..	4400	
Granulated zinc	3250	
Aluminium foil	3450	
Tin foil	2970	
Copper gauze	900	Green solution formed
Iron gauze	850	Brown solution formed
Soda lime	110	

The inhibitory action of metals throws a good deal of light on the mechanism of gumming because researches on the cause of knocking in an engine have shown that organic peroxides are reduced by metallic surfaces.

The determination of the gumming tendency of a spirit.—The gumming tendency of a fuel cannot be determined from one single measurement of the gum yield of the fresh fuel. The rate of gumming depends on the rate of oxidation, so it is necessary to submit the fuel to a period of oxidation and to determine the gum yield before and after oxidation.

A simple way of appraising fuels from the standpoint of resistance to oxidation and gumming is to incubate them, say, at 50° C., for a period of a few days in the presence of air or oxygen. It would be necessary to keep the conditions uniform and to employ glassware of the same quality and shape.

50 c.cs. of spirit contained in a litre hard glass flask and incubated at 50° in air for a week represents a drastic treatment to what actually occurs in practice over a long period of storage. The gum yield after this treatment is sometimes ten to twentyfold the original value, as is shown later, and the increase gives a comparative measure of the rate of gumming.

Accelerated gumming is effected by the action of light and by the addition of certain deleterious substances, whilst on the other hand the addition of hydroxy compounds, such as phenol or thymol or nitro compounds, etc., decreases the gumming rate.

The acceleration and inhibition of gumming.—Little is known with regard to the actual olefines which are most active in the gumming of cracked spirits. It is generally supposed that the di-olefines are the more active, mainly because of their occurrence in the so-called vapour phase spirits which usually have a relatively high gumming rate. Brooks has supplied experimental evidence with regard to this point, for example, myrcene with three olefine bonds gave a gum yield of 3960 compared with 1960 for limonene (two bonds) and 940 for pinene (one bond). With cracked spirits there does not appear to be any close correlation between the degree of unsaturation and the rate of gumming. The presence of one easily oxidisable constituent is sufficient to raise considerably the gumming rate of the whole spirit. Thus, Brooks found that the addition of 2 per cent. limonene to a refined spirit raised the gumming rate over fiftyfold.

It has been recorded that investigations at a refinery showed that the 30–40 per cent. fraction of a spirit formed more gum than all the other fractions combined, and it was suggested that by eliminating such unsuitable fractions by temperature control a better refined spirit could be obtained.

The following gumming rates were obtained with different fractions of cracked spirits (Tables 12 and 13).

The vapour-phase spirit (C) was fractionated by means of a 20 in. rod and disc fractionating column into ten fractions. These were

incubated at 35° C. for two months. The gum yields given in Table 12 were determined by the copper dish method.

TABLE 12.

Gum Yields from Various Fractions of Vapour-phase Spirit C, after Incubation.

Fraction.		Gum yield (mgs./100 c.cs.).
To 64° C.	10% volume	4200
64°— 70°	20% „	130
70°— 80°	30% „	70
82°— 87°	40% „	87
87°—100°	50% „	135
100°—108°	60% „	25
108°—115°	70% „	20
115°—122°	80% „	6800
122°—135°	90% „	150
135°—150°	100% „	3650

The remarkable jump in gumming rate passing from the 7th to 8th fraction can be best explained by assuming that the 8th fraction contains a hydrocarbon which readily forms organic peroxides, the active catalyst of gumming.

The results shown in Table 13 were obtained after exposing the fractions in the presence of air to light from a mercury vapour lamp for two hours :—

TABLE 13.

Gum Yields from Various Fractions of Cracked Spirit A after Exposure to Light from the Mercury Vapour Lamp.

Description.		Gum yield (mgs./100 c.c.).
Spirit A		120
1st 10% volume	6° to 92° C.	90
10—20% „	92° to 109°	278
20—30% „	109° to 144°	290
30—40% „	144° to 154°	310
40—50% „	154° to 161°	170
50—60% „	161° to 187°	120
60—70% „	187° to 191°	98

Acceleration of gumming by heat and light.—It was found that cracked spirits kept in the Laboratory were liable to gum much more rapidly than those stored in an outside store. This increase was due to the accelerating action of heat and light.

Cracked spirit A stored outside at an average temperature of 15° C. gave a gum yield of 16 after twelve months, whilst in the Laboratory at about 20° the gum yield reached 85.

Stored at 27° for 30 days, the increase in gum yield of cracked spirit A was 23 and when kept at 50° C. for 30 days the gum yield increased to 1380 mgs. per 100 c.c.

The following rate of gumming (Table 14, Fig. 2) was obtained with cracked spirits A and B contained in quartz test tubes (half filled) and exposed to the light from the mercury vapour lamp.

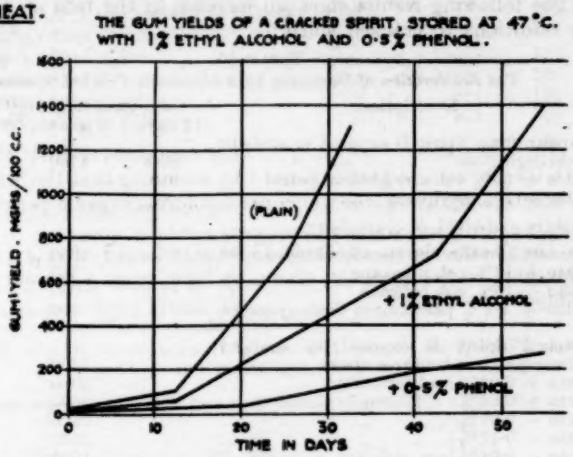
TABLE 14.

The Action of Light from the Mercury Vapour Lamp on the Gumming of :—

(*a*) Cracked Spirit A :						
Time of exposure in hours	0	4	6	8	10	15
Gum yield (mgs./100 c.c.)	80	240	400	650	720	1300
(*b*) Cracked Spirit B :						
Time of exposure in hours	0	1	2	4	6	
Gum yield	30	105	230	450	540	

THE ACTION OF HEAT AND LIGHT ON CRACKED SPIRITS.

(a) HEAT.



(b) LIGHT FROM MERCURY VAPOUR LAMP.

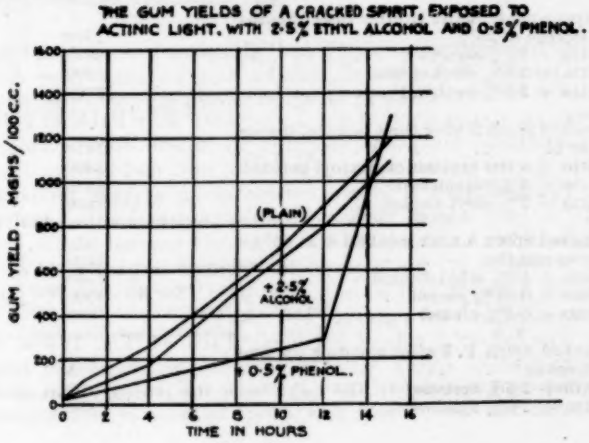


FIG. 2.

The influence of a large number of different substances on the gumming rate of several cracked spirits was investigated.

The complexity of the mechanism of gumming was demonstrated by the diversity of the results. Thus, blending with certain substances under certain conditions favoured the stability of one cracked spirit, but not another, whilst a substance could behave both as an inhibitor and an accelerator in the same fuel according to the temperature, age, etc.

The following results show an increase in the rate of gumming by additions to cracked spirit :—

TABLE 15.

The Acceleration of Gumming by Additions to Cracked Spirits.

Description.	Gum yield (mgs./100 c.cs.). 12 days.	1 month.	2 months.
Vapour-phase Spirit D exposed to sunlight through glass	800	1760	1950
Ditto + 20% vol. straight-run petrol	980	—	1570
Ditto + 1% ethyl fluid	—	—	4750
Refined Spirit E (naphthene base) exposed to sunlight through glass for three months		250	
Ditto + 10% vol. n-hexane		360	
Ditto + 10% vol. benzene		350	
Ditto + 0·1% para-amino diphenylamine		400	
Cracked Spirit B exposed to sunlight through glass for three weeks		1400	
Ditto + 0·02% lead tetraethyl		2080	
Ditto + 0·04% " "		2600	
Ditto + 0·08% " "		2800	
Ditto + 0·12% " "		2800	
Ditto + 0·04% iron carbonyl		1600	
Ditto + 0·12% " "		2200	
Vapour-phase Spirit H after three months' storage at 25°		2700	
Ditto + 10% acetone		3940	
Ditto + 2·5% ethyl alcohol		3000	
Ditto + 2·5% methylal		3700	
Cracked Spirit B after three months' storage at 25°		2410	
Ditto + a few crystals of benzoyl peroxide		3860	
Ditto + 5% paraldehyde		4460	
Ditto + 2% amyl alcohol		2850	
Cracked Spirit A after incubation at 45° for two months		1200	
Ditto + 10% ethyl alcohol		1550	
Ditto + 0·05% phenol		1900	
Ditto + 0·1% phenol		1600	
Cracked Spirit P. 3 after standing for four months		95	
Ditto + 2·5% acetone		98	
Ditto + 2·0% xylidine		850	

The effect of blending with straight-run spirit does not always result in a decrease of gumming rate in proportion to the dilution. Some results are given in Table 16, which support this conclusion.

TABLE 16.

The Effect of Blending with Straight-run Spirit on Gumming Rates.

Description.	Gum yield.
Cracked Spirit A after exposure to light	195
Cracked Spirit A (9 vols.) straight-run petrol (1 vol.)	175
Ditto (7 vols.) ditto (3 vols.)	170
Ditto (5 vols.) ditto (5 vols.)	170
Ditto (3 vols.) ditto (7 vols.)	120
Ditto (2 vols.) ditto (8 vols.)	110
Ditto (1 vol.) ditto (9 vols.)	70
Straight-run spirit	20

In E.P. 253,131, September, 1927, claiming the use as fuel of a blend of synthetic naphtha prepared from vapour-phase cracked spirit, it is stated that by blending with ordinary petrol considerably reduced gumming occurs, as shown by the results given, obtained by the action of light (Table 17).

TABLE 17.

Per cent. synthetic naphtha.	Per cent. petrol.	Gumming, mgs./100 c.c.
100	—	540
50	50	130
33	67	27
20	80	14
	100	7

A similar inhibitory action, by blending with straight-run spirit, etc., has been observed with vapour-phase cracked spirit C, as shown by the following results in Table 18 :—

TABLE 18.

Description.	Gum yield (mgs./100 c.c.)
Vapour-phase cracked Spirit C kept at 35° for two months	3900
Ditto with 1 vol. straight-run spirit	1300
Ditto with 1% cresol	250
Ditto with iron carbonyl, 5 c.cs./gall.	1900
Ditto with lead tetraethyl, 5 c.cs./gal.	3400

Brooks investigated the action of some sulphur compounds on the deterioration of cracked spirits and found that discoloration

and separation of tarry deposits were caused by the action of small amounts of sulphur dioxide.

Similar results with vapour-phase spirit C have been obtained by the addition of a little sulphuretted hydrogen. The products of oxidation of cracked spirits other than peroxides, namely, aldehydes, ketones, acids, etc., were found to have no accelerating effect on the gumming rate, whilst water possessed a considerable inhibitory action. Some results are given in Table 19 with regard to the action of sulphur compounds, water and aldehydes, etc., on the gumming rate.

TABLE 19.

Influence of Aldehydes, Water, etc., on the Gumming Rate.

Description.	Gum yield (mgs./100 c.cs.).	
V.p. cracked Spirit C after exposure at 20° to sunlight through glass for 15 days	4850	
Ditto over water..	2875	
Ditto + 2·5% acetaldehyde	3010	
Ditto + 2·5% paraldehyde	2780	
Ditto + 2·5 acetic acid	3710	
Ditto + gum (from V.p. spirit)	4800	
Refined Spirit P after standing at 20° in dark for 10 months	1720	
Ditto + a little sulphuretted hydrogen	950	Separation of tarry deposit discoloration.
Ditto + 1% amyl nitrite	490	Ditto.
Ditto + 0·2% thymol	300	
Ditto + 0·5% Eugenol	250	
Ditto + 2·5% methyl alcohol	3050	
Ditto + 0·5% benzyl alcohol	450	
Ditto + 0·25 phenol	280	

The action of inhibitors on the gumming rate throws considerable light on the mechanism of gumming, since the inhibiting substances such as thymol or cresol, are well known "anti-oxygens," inhibiting the formation of organic peroxides.

Water has an action on organic peroxides, decomposing them into aldehydes, etc. The inhibiting action of water is regarded by Brooks as strong evidence in support of the view that organic peroxides precede gumming.

Further results obtained with additions of organic substances to cracked spirits with regard to decrease in the rate of gumming are given in Table 20.

TABLE 20.

The Inhibition of Gumming by Various Organic Substances.

Description.	Gum yield (mgs./100 c.cs.).
V.p. Spirit D (after exposure to sunlight)	1950
Ditto + fifth volume benzene	1450
Ditto + 0·5% phenol	950
Ditto + 10% ethyl alcohol	200
Ditto + 10% methyl alcohol	1000
Refined Spirit E (after exposure to sunlight)	250
Ditto + 10% cyclohexane	100
Ditto + 2·5% methyl alcohol	50
Ditto + 2·5% ethyl alcohol	75
Ditto + 0·2% phenol	50
Ditto + 0·1% lead tetraethyl	80
Ditto + 0·5% cresol	60
Cracked Spirit A (after exposure to U.V. light)	550
Ditto + 0·25% p. amino phenol	290
Ditto + 5% acetone	440
Ditto + 20% benzene	250
Ditto + straight-run petrol	390
Ditto + 5% ethyl alcohol	430
Cracked Spirit B (after incubation at 47°)	1210
Ditto + 0·5% phenol	30
Ditto + 2% amyl alcohol	710
Ditto + 1% toluidine	660
Ditto + 0·5% thymol	20
Ditto + 0·5% p. nitro toluene	270
Ditto + crystal of hydroquinone	12
Ditto + 2% eugenol	32
Ditto + 2% benzylamine	122

SUMMARY.

The gumming of cracked spirits is essentially an oxidation process involving the initial formation of organic peroxides. The rate of gumming is increased by aeration, by rise in temperature, by the action of actinic light, and by the presence of deleterious substances, such as certain sulphur compounds and substances which readily become peroxidised.

Deterioration is inhibited by absence of aeration, by the addition of "anti-oxygens" such as phenol, thymol, etc., and to some extent by surfaces, such as that of soda lime, iron or copper gauze, water, etc.

The anti-knock properties of cracked spirits are impaired by the gumming and general deterioration during storage in presence of air. This is due to the fouling of the engine interior, to the presence of organic peroxides which strongly induce knocking and to the partial removal of hydrocarbons of higher anti-knock value. The determination of the gum content of a fuel of suitable volatility can be conveniently and quickly determined with a fair degree of precision by evaporation in a copper or glass dish on an actively boiling water bath. The employment of special methods involving evaporation in steam or in inert gases requires elaborate apparatus and the duration of the test is usually longer. Results with the use of steam are equivocal since steam is not without action on the gum.

Gum Formation in Cracked Gasolines.

By C. R. Wagner and Julius Hyman.

The gum forming tendency of highly unsaturated hydrocarbons, although known for years to the coal tar industry, received relatively little attention from petroleum refiners until after the development of the liquid phase cracking art. W. A. Hall was a pioneer in this field, describing in 1915[1] the gummy resins formed by evaporation of the gasoline made by his vapor-phase cracking process. Considerably later Smith and Cooke[2] proved the presence of aldehydes in "gummy" gasoline, while Brooks[3] advanced the theory that gum formation was due to polymerization of organic peroxides.

The literature on the chemistry of gum formation in cracked gasoline is very meagre, a situation which is not surprising when one considers the lack of accurate information concerning the composition of such gasolines. In this paper the authors can give only a preliminary report on the work in progress and suggest a theory which serves to explain in part the results obtained. It is hoped that this theory may arouse new interest in this subject, which will result in real progress being made toward a solution of one of the important problems facing the industry.

The method used for determining the gum content of gasoline by the authors is a modification of the method of Smith and Cooke.[4] The authors, in attempting to develop a method suited to routine work in laboratories concerned with the checking of gasolines being marketed, found that for such practical work a steam bath could be used instead of the steam oven with an atmosphere of steam. Considerable steam escapes around the dish and rises past the edge of the dish, thus preventing excessive contact with air. An actively boiling bath insures complete evaporation of the sample in thirty minutes or less. Results by this method do not check each other as closely as is desirable when much gum is present, and they are always somewhat higher than results by the steam oven method. This defect is not serious, however, when used for the purpose described.

Contrary to popular belief, the colour of a gasoline is no indication of its gum content. Many samples having a very yellow colour have been found gum free, while others which were +25 Saybolt or

[1] *J. Inst. Petr. Techn.*, **1**, 147, 1915.
[2] Bureau of Mines Reports Serial No. 2394, 1922, and No. 2686, 1925.
[3] *J. Ind. and Eng. Chem.*, **18**, 1198, 1926.
[4] *Loc. cit.*

better gave very heavy gum deposits. However, on evaporation "gummy" gasoline develops more and more of a yellow colour until finally a residue is obtained that may vary in colour from pale amber to deep brown and which has a consistency varying from that of an oily liquid to a solid mass. Usually a solid brown gum is formed which is insoluble in petroleum ether, partially soluble in benzene, and completely soluble in acetic acid and alcohol. When dissolved in alcohol the colour of the gum persists in the solution. These data on colour and solubility point to a conclusion which appears to have been overlooked quite generally—*i.e.*, that so-called "gummy" gasoline actually contains little or no gum in solution, but contains rather the gum forming materials which are then resinified by heat during evaporation.

This conclusion has been checked in the following manner. A gasoline which gave a large amount of gum on evaporation was treated with a small quantity of strong alcoholic potash. A violent reaction occurred and formation of a reddish brown resin. Dissolved in alcohol the coloration of this solution checked very closely with the colour of a solution of the gum formed by evaporation of an equal quantity of gasoline. This suggests the possibility of a colorimetric method for determining the gum content of gasolines.

Although some of the common aldehydes are present in "gummy" gasoline, Brooks[1] showed that they alone were incapable of forming appreciable quantities of gum. The authors have checked his experiments with similar results. When technical crotonaldehyde was dissolved in Cabin Creek straight run gasoline, however, and exposed to the action of oxygen and light, quite different results were obtained. The gum formed by evaporation of these solutions of crotonaldehyde possesses properties practically identical with the gum formed by the evaporation of gasoline, which would seem to indicate at least a similarity of origin.

TABLE 1.

	Gum per 20 c.c. of sample.	
	Fresh.	Old.
5% crotonaldehyde solution ..	0.0045	0.0428
10% crotonaldehyde solution ..	0.0209	0.0836

Brooks[2] explained the formation of aldehydes by the decomposition of peroxides. A sample of vapour phase cracked gasoline containing 50 per cent. or more of olefines, but no gum, was added to an acidified solution of potassium iodide. No iodine was

[1] *Loc. cit.*
[2] *Loc. cit.*

liberated. When the same sample of gasoline had been exposed to the action of light and oxygen for several days it liberated large quantities of iodine from such a solution. On evaporation this gasoline, which now contained peroxides, left a quite appreciable residue of gum. It is apparent that some relation therefore exists between peroxides and gum formation.

A sample of highly unsaturated gasoline that had been exposed to an oxidizing atmosphere for months was distilled in vacuo to a 28 per cent. bottom. This residue had an acid number of 0·75 and a saponification number of 13·4. It gave a very strong test for peroxides, while an ultimate analysis of the material indicated the presence of 0·2 per cent. oxygen (by difference). It was attempted to run an A.S.T.M. distillation on this residue, but while the first 40 per cent. was distilling over a series of violent explosions occurred in the flask. With each explosion vapours of acrolein were thrown off, and this continued until a temperature above 360° F. was reached. A heavy resinous mass was finally left in the flask amounting to about 10 per cent. of the oil charged, although the end point obtained in the distillation checked very closely with the end point of the original gasoline. Neither the distillate nor the residue gave positive peroxide tests, but the distillate gave a strong test for acrolein. This would indicate that evaporation of the peroxides had caused their decomposition, and that acrolein, among other substances, was formed during the process.

The residue was separated on the steam bath into two products: (1) a light red oily liquid having a specific gravity of 0·9027, an acid number of 4·49 and a saponification number of 32·41; and (2) a black asphalt like resin having an acid number of 64·86 and a saponification number of 307·9. Further data on these materials are given in Table 2 along with data from the above-mentioned paper by Smith and Cooke:—

TABLE 2.

		Smith and Cooke's data.			
	Oily liquid.	Black resin.	Soluble resin.	Insoluble. resin.
Hydrogen	12.61	8.00	7.39	6.75
Carbon	83.51	73.59	69.48	70.62
Oxygen	3.28	17.17	19.93	21.06
Ash	—	—	2.78	1.00
Sulphur	0.60	1.24	0.28	0.50
Nitrogen	—	—	0.14	0.07

A sample of vapour phase cracked gasoline nearly free from gum was placed in a tightly stoppered bottle, in which the air had been displaced with oxygen, and set in the dark. The rate of gum formation under such circumstances, where catalyzers and light or heat are absent, is seen to be very low.

TABLE 3.

Time in days.	....	Gum/20 c.c.
0	....	0.0004
16	....	0.0004
36	....	0.0006
45	....	0.0010

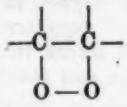
Table 3 shows clearly the so-called phenomenon of the "period of induction." Once this period is over, gum formation goes on apace, especially at elevated temperatures. This was noticed particularly in the following experiment: 100 c.c. of gum free vapour phase gasoline was placed in a steel calorimeter bomb and the bomb then filled with oxygen to 310 lbs. pressure. A pressure gauge was fitted to the bomb, and the whole bomb immersed in boiling water. Table 4 shows the rate of oxygen absorption:—

TABLE 4.

Time.		Pressure.		Difference.
Start	....	310	....	—
10 min.	....	270	....	40
20 min.	....	220	....	50
30 min.	....	160	....	60

The oxidized gasoline smelled strongly of acrolein and the gallic acid test (Mulliken) showed acrolein to be present.

At room temperature, in the dark, the phenomenon of auto-oxidation is very much less pronounced, which would indicate the formation of a fairly stable intermediate compound. Recent work by Stephens,[1] as well as the earlier work of Engler and Weissberg,[2] on the air oxidation of olefines indicates the relative stability of peroxides of the type



and such compounds, it appears probable, are formed in cracked gasolines exposed to the action of air or oxygen.

It is well known that "gummy" gasolines impart an acid reaction to water with which they are shaken. It therefore seemed possible, in view of the inactivity of the olefine bond, *per se*, that the catalytic agent involved was an acid. This view was strengthened by the discovery that a trace of hydrogen chloride gas not only causes polymerization in gum free vapour phase cracked

[1] *J.A.C.S.*, **50**, 568, 1928.

[2] Ber. **33**, 1094, 1900. See also: Bach., *Compt. rend.*, **124**, 951, 1897; Engler and Wild, *Ber.*, **30**, 1669, 1897; Engler and Frankenstein, *Ber.*, **34**, 2933, 1901; Staudinger, *Ber.*, **58**, 1075, 1925; Jorissen and Van der Beek, *Rec. trav. chin.*, **45**, 245, 1926.

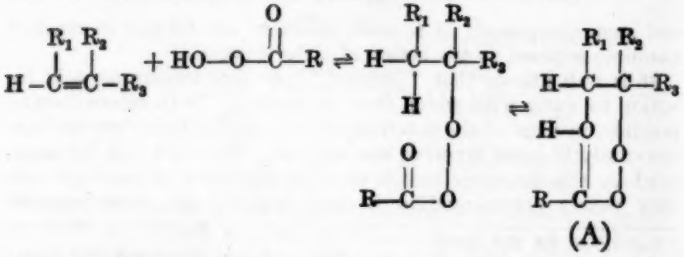
gasoline, but also promotes profound oxidation. Glacial acetic acid shows only a faint catalyzing action in the oxidation of such gasoline.

TABLE 5.

Trace HCl gas.			5% glacial acetic acid.		
Days.		Gum/20 c.c.	Days.		Gum/20 c.c.
Start	..	0.0001	Start	..	0.0004
5	..	0.1256	16	..	0.0021
9	..	0.2233	45	..	0.0036

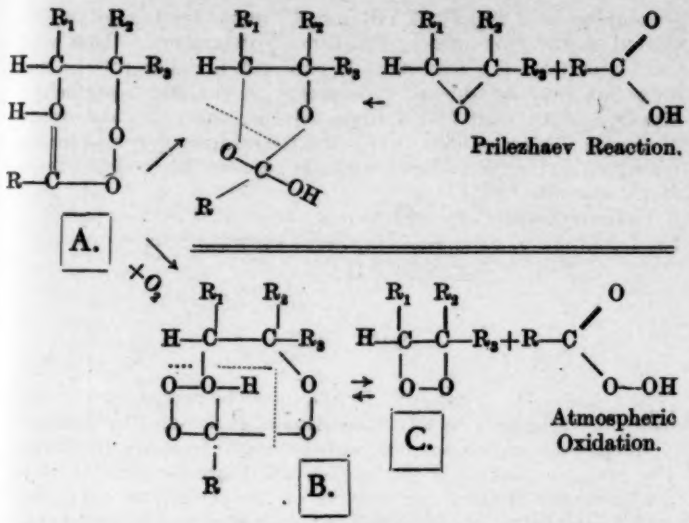
Alpha-crotonic acid acted in about the same manner as acetic acid. It would appear, therefore, that if the catalyzing substances are acids, they must then be either stronger or at least better able to supply active oxygen than the common organic acids. This suggests the thought of per-acids, which is also consistent with the behaviour of solutions of aldehydes and cracked gasolines exposed to oxygen and light. Such solutions give strong tests for peroxides. That such per-acids, however, would have to react according to a scheme different from the Prilezhaev reagents[1] is evident from the fact that the oxidation is auto-catalytic—that is to say, that more catalyst must result from a reaction than was there originally. Rather, the action on the double bond is probably the addition of two oxygen atoms instead of one, resulting in the formation of compounds of the type postulated by Engler and Wild.[2] Such compounds could then oxidise further, splitting the double bond completely with the formation of aldehydes and ketones, the former then absorbing an oxygen molecule[3] for the further formation of the catalytic per-acid.

If, however, one considers that atmospheric oxidation is a slow process, and that molecular oxygen is always present, a simple scheme of reaction for the "gum-forming" mechanism can be devised, which furthermore shows the relationship which may exist between such a reaction and the Prilezhaev reaction:

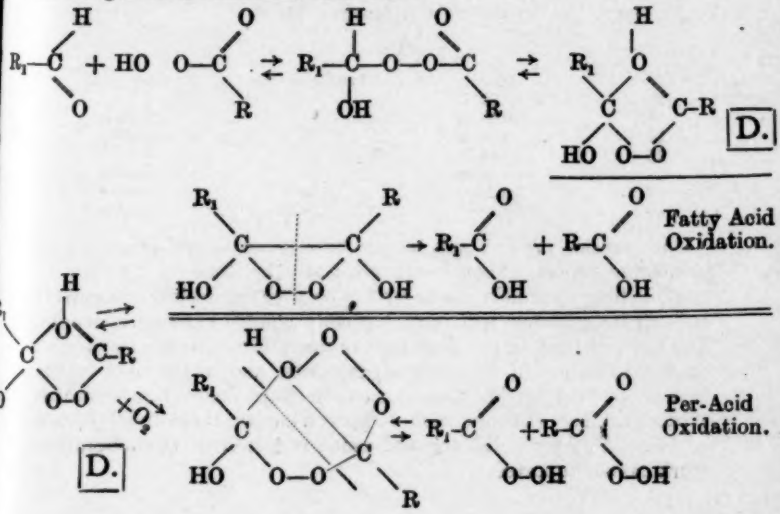


(A)

[1] *Ber.*, **42**, 4811, 1909.
[2] *Ber.*, **30**, 1669, 1897.
[3] See Kiss and Demeny, *Rec. trav. chim.*, **43**, 221, 1924.

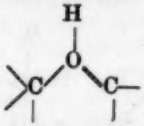


Thus the per-acid would be regenerated, along with the hydrocarbon peroxide, which latter can break into an aldehyde and a ketone, the aldehyde being then further oxidized in the presence of the per-acid, somewhat as follows :—



Compounds of types (A), (B) and (C) (equation 1) may be considered as the gum-forming constituents of gasoline. That compounds of type (D) (equation 2) play but a minor role in gum formation may be shown by exposing to sunlight acetaldehyde dissolved in an inert hydrocarbon solvent, under an atmosphere of oxygen. After an hour's exposure, the solution shows an intense peroxide reaction, but gives very little gum by the modified Smith and Cooke test.

The hypothesis here presented is of interest in so far as it postulates the formation of oxonium compounds containing the active group



(types A and D). That such a group must be comparatively easily oxidizable follows from a consideration of electronic displacements.

Interesting conclusions may also be drawn from the hypothesis. For example, according to the viewpoint herein expressed, if the acid strength or oxidizing activity of the per-acid is suppressed, and if external agents, such as light, excessive heat or atmospheric peroxides are absent, then the oxidation of the gasoline should be retarded indefinitely. How well this conclusion is borne out by the facts is shown in Table 6. The hydroquinone acts to reduce the per-acid to an inactive organic acid, whereas the ammonia keeps down the hydrogen ion concentration.

TABLE 6.

Days.	Plain.	Hydroquinone.	Ammonia.
Start	0.0057	—	—
8	0.0143	—	0.0050
18	0.0243	—	0.0070
25	0.0399	—	0.0052
38	0.0629	—	0.0060
52	0.2600	0.0098	0.0087
100	—	0.0085	0.0050

The writers present this paper merely as a preliminary and pioneering report. Much work must still be done on "gum" in gasoline before the field can be trod upon with any feeling of security, and future evidence will most probably change existing concepts. The research staff of the Pure Oil Company is continuing its studies on the oxidation of unsaturated gasolines, and in the near future it is hoped that further data can be offered in connection with this problem. The authors wish to acknowledge their indebtedness to Geo. W. Ayers, Jr., for assistance rendered in the laboratory work herein reported.

The Determination of Existent Gum in Cracked Distillates.

W. S. Norris, Ph.D., A.I.C., A.R.C.S., D.I.C., F.C.S., and F. B. Thole, D.Sc., F.I.C., F.C.S. (Member).

It now appears to be generally agreed that in order to describe a cracked distillate with respect to gum it is necessary to distinguish between existent gum and potential gum. Only existent gum can affect engine performance—by becoming deposited in the petrol tank and pipes, in the carburettor and induction system, and above all, on the inlet valves—whilst the gum forming tendency will determine how much gum will have been formed after a specified period of storage.

In this paper preliminary notice is given of a method that has been evolved for the rapid and accurate determination of the gum actually existing in the spirit at the moment of test.

It is by no means a simple matter, in the first place, to define "existent gum." The word "gum" is generally used in the sense of a solid or semi-solid, non-volatile or almost non-volatile (though not necessarily heat-stable) solute, which remains as a resinous or gummy residue when the volatile constituents of the spirit are removed by evaporation, and which may be deposited from solution at the ordinary temperature if sufficient accumulates in the spirit. The introduction of the word "non-volatile" suggests the idea of a temperature limit. It is held that this idea is implied whenever the estimation of gum or its deposition in an engine intake system is mentioned. In the usual glass-dish method of estimating gum the term "gum" means whatever is non-volatile under the conditions (time and temperature) of the test. The gum deposited initially on an inlet valve—as distinct from the harder resin to which the prolonged action of heat may convert it—is material which is non-volatile under the conditions of the inlet system. The temperatures in these examples are quite widely separated. In general, when the word "gum" is used, it is implied that the petrol is evaporated by some means not necessarily specified, and that any solid or semi-solid, resinous or gummy residue is "gum."

Actually, great caution is necessary in endeavouring to draw lines of demarcation between existent gum, potential gum and other constituents of a cracked distillate. The processes by which hydrocarbons are converted to "gum" certainly involve a number of steps which include oxidation and polymerisation—or, more

strictly, condensation. It seems fairly certain that preceding the final gum there are formed certain liquid constituents that may be termed "pre-gum." These are volatile or partly volatile, though for the most part of higher boiling point than the final boiling point of the freshly distilled, newly refined distillate. At ordinary temperatures the "pre-gum" is gradually converted into gum, and this change is accelerated by the action of heat. The conversion of pre-gum into gum does not appear to require the presence of atmospheric oxygen. Thus it has been found that additional gum to that already present is formed if a boiled-out, oxygen-free sample of cracked distillate is heated in an oxygen-free atmosphere in an autoclave—although less is formed than in the presence of oxygen. It follows that the amount of gum remaining when a sample of cracked petrol is evaporated will depend not only upon the temperature but also upon the rate at which evaporation is carried out. Existent gum will be deposited in amount independent of the conditions employed, but additional gum will be formed in an amount probably greater the higher the temperature, but certainly greater the more protracted the evaporation and depending also on the degree of exposure to oxygen during the evaporation process.

In our opinion, therefore, actual or existent gum should be defined as the residue left by the instantaneous evaporation of the sample in question, carried out in a non-oxidising atmosphere and in such a manner that no conversion of "pre-gum" to "gum" can occur, though this is of little moment with instantaneous evaporation.

The material to be determined is therefore defined in terms of an ideal test, the conditions of which cannot be completely realised in practice, although they can be very closely approached by the method of analysis described in this communication. Thus the question of temperature of evaporation immediately arises. It has already been indicated that in speaking of gum or of its estimation some arbitrary temperature of evaporation is almost invariably implied. It is therefore held that any convenient temperature may be chosen at which the gum-free distillate would be completely volatile under the conditions of test, and that the residue then obtained may fairly be regarded as the actual gum content of the sample, provided that evaporation is carried out with sufficient rapidity to avoid substantially the formation of additional gum.

It would seem, however, that as the worst deposits from a gum-containing spirit form on the head and stem of the inlet valve, the most desirable temperature would be one approximating these conditions; *i.e.*, about 200° C.

In short, the dish methods hitherto employed suffer from the following disadvantages:—

1. The period of evaporation is long and differs for samples of varying volatility. It is also affected to an uncontrolled degree by air currents in the laboratory.

2. The degree of oxidation (if the evaporation is conducted with exposure to air) is not under control, and the degree of heat-polymerisation also varies with the rate of evaporation of the particular sample.

3. The results must be affected considerably by the thickness and thermal conductivity of the material of the dish, which greatly influence the rate of evaporation.

4. The material of the dish probably exerts a specific catalytic effect, when the evaporation is carried out over a long period with exposure to oxygen.

5. The usual final temperature of the "gum" (a few degrees below 100° C.) differs considerably from the normal temperature of an inlet valve upon which gum deposits usually accumulate to the most serious extent.

6. Evaporation in an atmosphere of steam, which eliminates some of these objections, still involves a considerable and unstandardisable period of heating, while chemical action between steam and organic peroxides is known to occur.

We have consequently sought for a test which will embody the following essentials:—

1. Instantaneous evaporation of the whole of the sample, so that the effects of long heating are reduced to a minimum.

2. Evaporation at a temperature (about 200° C.) approximately equal to that of an inlet valve, so that the deposit is comparable with that which will form on this valve in a motor engine. At this temperature, too, the rapid evaporation aimed at can be readily achieved.

3. Exclusion of air, because the effects of oxidation are not well understood at present. With flash evaporation, however, there is very little time for any oxidation of the hydrocarbons in the spirit to occur; the same state of affairs exists in an engine induction system.

4. Maintenance of an accurately controlled temperature during the whole of the evaporation and exposure of every portion of the sample to the same temperature for the same period. This again approximates most closely to actual engine conditions.

A test based on these principles should give an accurate indication of the actual gum in a spirit and a measure of the deposit which such spirit will form in the inlet system of an engine.

The method of analysis developed on this basis is as follows:—

A spiral tube of Pyrex glass, 45 cm. long and 6 mm. internal diameter (thus giving adequate evaporative surface), is mounted in an oil bath maintained at 200° C. or, preferably, in an air oven maintained at 220° C. The inlet of the spiral is fitted with a cork which carries: (a) a tube through which nitrogen is passed through the system at a controlled rate, (b) a tap funnel by means of which a measured sample of spirit is introduced at a definite rate, drop by drop.

Vapour from the exit of the spiral, mixed with nitrogen, is led off through a suitable tube to a condenser. The spiral tube is weighed before and after the evaporation of the sample and subsequently cleaned by soaking in chromic acid mixture.

The method is therefore one of flash evaporation. Each drop of the sample is exposed to the action of heat for a very short space of time, which is practically independent of the volatility of the petrol undergoing test.

The temperature of the oven in which the spiral is heated, the rate of flow of nitrogen and the rate of introduction of the sample, can all be controlled to within limits closer than will affect the result.

The exact design of the spiral tube and the other conditions of test must, to some extent, be interdependent. It appears, however, from the results so far obtained that quite large variations in these conditions produce relatively small changes in the results, which therefore are essentially significant in themselves as a measure of actual gum, and are not merely relevant to the conditions employed.

The following conditions have been provisionally adopted for testing cracked distillates with end points 200°—210° C.:—

Temp. of air oven	.. ..	220° C.
Velocity of nitrogen	.. ..	120 c.c. per min.
Sample (usually 25 c.c.) introduced at	.. ..	3 drops per sec.
	i.e.	2·7 c.c. per min.

The degree of concordance of results is illustrated by the following typical figures, obtained by the evaporation of 25 c.c. of the same sample of gasoline.

Gm. gum from 25 c.c.	Gm. gum per 100 c.c. (calc.).
0.0024	0·0096
0·0021	0·0084
0·0024	0·0096
0·0020	0·0080

This sample of petrol gave 0·030 gm. of gum per 100 c.c. by evaporation of 25 c.c. in a glass dish on the open steam bath.

The temperature of operation was originally reached when working with narrow spiral tubes ($\frac{1}{8}$in. internal bore) heated in an oil bath. Although the conditions have since been changed, the following results obtained with varying temperatures but constant

gas velocity and rate of introduction of the sample are of interest—partly because they afford a further example of the reproducibility of results:—

Temp.	Petrol.	Vol. of sample. c.c.	Gm. gum found.	Gm. gum per 100 c.c.	Mean.
180°	(A)	50	0·0059	0·0118	0·1106
180°	(A)	50	0·0057	0·0114	
200°	(A)	100	0·0072	0·0072	0·0075
200°	(A)	50	0·0039	0·0078	
220°	(B)	50	0·0044	0·0088	
220°	(B)	50	0·0046	0·0092	0·0094
220°	(B)	50	0·0046	0·0092	
220°	(B)	50	0·0053	0·0106	

Sample (B), 25 c.c., in a glass dish on the steam bath, gave

0·0173 gm. gum
0·0172 „
or 0·0692 } mean 0·0690 gm. gum per 100 c.c.
0·0688 }

From these experiments with narrow spirals 200° appeared the most suitable temperature under the conditions employed. At 180° the heat transfer was insufficient, and the tube tended to load up; it was therefore impossible to evaporate the sample sufficiently rapidly.

It has now been found more convenient to mount the spiral tubes in an air bath maintained at 220°. Under these conditions 25 c.c. of sample can be evaporated in 10 mins., a speed of operation much superior to that attainable in a dish method.

It is felt that rapidity of removal of the vapour is of even more importance than exclusion of oxygen. Confirmation of this was obtained by evaporating 25 c.c. of the same cracked petrol at the same temperature, but (1) in air (8 bubbles/sec.) and (2) in nitrogen (8 bubbles/sec.) with the following results:—

Gm. gum per 100 c.c.		
Air.	Nitrogen.	
0·0264	0·0225	
0·0261	0·024	
0·0262	0·0235	Mean

The influence of atmospheric oxygen, under flash-evaporative conditions, is quite small, though it is obviously much more important in a dish test which lasts for some hours.

The procedure for carrying out a gum determination as well as the interpretation of the results in terms of the tendency of the spirit to foul the inlet system of an engine is perforce arbitrary to a certain degree. Nevertheless, it would appear that the procedure should approximate as nearly as may be to the actual conditions of gum deposition in an engine, and the results so far obtained have convinced the authors that the method here outlined is fundamentally more sound as well as superior in accuracy and rapidity to dish tests.

The President said that, in view of the fact that so many chemists were present, and that the subject with which the papers dealt would arouse a certain amount of controversy, he did not desire to take up the time available for discussion. He noticed, however, that his old friend, Mr. Anfilogoff, was present, and this reminded him of the fact that fifteen years ago there were a great many thousand tons of so-called vapour phase cracked spirit produced at Thames Haven. He remembered how often observations were made and results obtained, which were subsequently rediscovered by others at a later date, and he quoted as an example the statement that an oxidised cracked spirit was explosive. He remembered on many occasions distilling reasonably fresh samples of that particular material in Mr. Anfilogoff's laboratory, with the result that when about three-quarters of the spirit had volatilised the contents of the flask blew up. That was a phenomena which, after fifteen years, was brought to light again in the papers that had been read.

DISCUSSION.

Dr. F. B. Thole emphasised the fundamental difference between any form of the dish test and the actual condition of affairs when the spirit in question was used in an engine. In the former, a fractional distillation took place over a relatively long period of time, whereas the actual circumstances of use amount practically to a flash evaporation of all the constituent hydrocarbons simultaneously. It was on this account that he urged that any method of estimating gum content should be based on the principle of flash evaporation. When Colonel Auld stated that "no evaporation test is really satisfactory," he was only indicating the unsatisfactory nature of an evaporation test which takes a long and indefinite period of time.

While considerable attention had been directed to the determination of existent gum, little progress had been made with the problem of determining the "potential gum" of a spirit. The Voorhees and Eisenger Method was the only one available, and this awaited substantiation from other sources before its acceptance. It was also too long and tedious an operation to be suitable for the control of a refining operation. The use of other accelerants of gumming demands attention. Ultra-violet light has been tried, but it gives results difficult to correlate with those of time, and moreover it is almost impossible to standardise this accelerant in view of the variability of mercury lamps.

Dr. Thole drew attention to the extremely powerful catalytic effect of acids in stimulating gum formation. The effect of these

is important since traces of acids, especially those derived from sulphuric acid, might be introduced into the spirit during refining treatments, while it seemed probable that per-acids derived from fission of the intermediate peroxides played a most important part in catalysing spontaneous gum formation. In this connexion it was very significant that Dr. Mardles showed soda lime and ammonia to be powerful inhibitors while copper and iron gave visible signs of conversion into cupric and ferric salts; it was difficult, however, to see why zinc should not have shown similar signs of corrosion.

Mr. W. H. Hoffert said he was very interested to find, on reading the papers, that the experiences of the authors with regard to the gumming of cracked petrols were very similar to those of Mr. Claxton and himself working with benzoles containing unsaturateds. Their work was commenced in 1924, and had been reported in detail in the 1926–1929 Reports of the Joint Research Committee of the National Benzole Association and the University of Leeds.

He desired to emphasise, however, that the results obtained with one type of fuel did not necessarily apply strictly to other types. For example, there was a distinct difference between petrols and motor benzoles, which perhaps had not been fully appreciated by Col. Auld. Motor benzoles had "end points" of about 150° C., whilst petrols usually had end points of 200° C. or more. He thought that explained the differences between Col. Auld's experiences and their own, concerning whether oxidation took place during a plain evaporation test. A benzole evaporated fairly rapidly when heated on a steam bath, and unless air was actually streamed over the surface of the liquid, as in the test used by Dr. Mardles, the vapour "blanketed" the surface of the liquid and prevented air oxidation during evaporation. When a petrol was evaporated, vapour formation took place relatively slowly towards the end, and the surface of the liquid was exposed to air oxidation.

That motor benzoles did not oxidise to any extent during evaporation was shown very definitely by the fact that benzoles containing a high proportion of unsaturateds could be prepared in the laboratory or on the works, which on evaporation immediately after distillation gave only a few milligrammes of gum per 100 c.c., although they were unstable and even after a few days gave large residues on evaporation. It was also found that benzoles, after varying periods of storage, gave practically the same residues when evaporated under vacuum at atmospheric temperature as were obtained when evaporated on a steam bath at 100° C. He thought Col. Auld would find that Mr. Claxton and himself were careful to point out that their conclusions with regard to a plain evaporation test only applied to spirits with a comparatively low end point

(1928 Report, p. 27). Even with petrols it was only oxidation of the higher boiling constituents which took place.

Since under practical conditions benzoles were subjected to varying periods of oxidation during storage, they were quite unable, for the reasons stated, to accept a gum test for benzoles, which merely involved plain evaporation, and were using the oxidation method of determining tendency to gum formation already referred to. In devising this method they were influenced by the necessity for a test which only required simple apparatus, and which could be carried out in a relatively short time. In that connexion he was particularly interested in Dr. Thole's flash evaporation method, which, if employed after oxidation, would materially shorten the time required to carry out an oxidation test.

Conflicting statements were made in the papers as to the influence of copper on gum formation. In that connexion Mr. Claxton and himself obtained some evidence that the effect of copper was governed by the presence or absence in the fuel of impurities which either tended to promote or retard gum formation. Thus, in the absence of inhibiting impurities, copper retarded gum formation in benzoles; in their presence it accelerated it. Gum formation in copper was usually entirely different to gum formation in containers in which motor fuels were usually stored.

Another point which must be realised was the extremely sensitive character of the reactions involved in the gumming process to traces of certain impurities, which either tended to inhibit or accelerate resinification. Thus an effect was produced by 1 part of cresol in 50,000 parts of benzole, and resinification could be completely arrested by 1 part in 2,500 parts of benzole. There was an optimum concentration of inhibitor which produced the maximum effect, and if this was exceeded to any appreciable extent resinification might be accelerated and not retarded. Similarly, if an impurity tending to inhibit resinification was already present, as indicated by an induction period, the addition of another inhibitor might accelerate resinification instead of retarding it. Those views might help to explain why Dr. Mardles found that substances capable of inhibiting oxidation when added to cracked petrols in some cases retarded, and in others accelerated, gum formation.

In conclusion, he desired to mention that the main facts and conclusions arising from the investigations of Mr. Claxton and himself on the resinification of the unsaturateds in benzoles were summarised early in the present year in a paper which he hoped would be published in the next report of the Committee.

Mr. N. A. Anfilogoff said he had been very interested in Dr. Mardles' paper and congratulated him on the work he had

carried out in his laboratory. He would not discuss in detail the number of tests that had been dealt with but he proposed to give a few practical hints. He thought the epitomy of Colonel Auld's paper was contained in the statement that "A petrol may show a gum-free test to-day, but if by to-morrow it is full of gum to-day's test has little meaning." Neither has it, whatever test was employed. He suggested that it was useless to have any tests at all if they were devised with the sole object of minimising the amount of gum which would be obtained from the test. As a practical refiner he wanted to see the maximum amount of gum that could be obtained in the test in order to know where he had gone wrong in his refining. By the same kind of reasoning he did not think a great deal either of the flash test, although it took merely a few seconds, for the following reason. He had not found a great deal of difference between making the test in a copper bowl or in a silica bowl; but he wished to remind his colleagues that there was something in the appearance of the gum in the bowl. From the appearance of the gum in the bowl and from the way in which it formed in the bowl and the condition of the gum, as also the pattern it left, the refiner could glean a great amount of information as to whether the fault lay in the refining or in the cracking. With regard to the question of deterioration on storage, the President had already referred to some of their experiences fifteen years ago. He desired in that connexion to give a suggestion which had been proved by practice. When large quantities of cracked spirit, whether refined or unrefined, were being dealt with, it should be remembered that evaporation took place in the tank from the top surface of the tank. It is also known that the temperature at the top of the tank is usually higher than the temperature at the bottom of the tank. As the evaporation takes place from the top surface and the lighter hydrocarbons evaporate, the remainder also naturally becomes heavier in specific gravity. If the tank is left untouched for some time the evaporated top surface layer which has become heavier in specific gravity, and perhaps also oxidised, permeates through the tank towards the bottom and so in time the whole of the tankfull can become deteriorated by the solution of the heavier and oxidised particles in the rest of the bulk. It is, however, a fact that there is a period of equilibrium when the heavier hydrocarbons are at the top of the tank—due to the elevated temperature. If, therefore, deliveries of spirit were to be drawn off from the top of the tank—while a fresh surface would be exposed—the evaporated and more or less oxidised portions would be delivered first, and so deterioration of the remaining material in the tank considerably postponed.

Mr. J. E. Hackford said that he had been very much interested in the question of gumming for a considerable time, and had

experienced the same difficulties in refining to which Mr. Anfilogoff had referred. But he was more interested in the whole question of gumming from quite another point of view. He had recently examined many samples of an African crude oil. the steam distilled spirit from which consisted almost entirely of alicyclic compounds, limonene predominating. Upon evaporation this spirit yielded a gum very much like gum arabic in appearance. This forms an example of a gum naturally present in a crude oil.

On the other hand, those gums present in "cracked spirit" may be said to be artificial gums, but in both cases there still remains a further distinction to be made. In both the natural and artificial spirits there may be potential gum-forming compounds. While a gum estimation tells us the amount of gum present to-day, a knowledge of the nature of these gum forming compounds and a means of estimating them would give us an indication of the amount of gum that we might expect to find in the near or distant future, as acknowledged in the paragraph of Col. Auld's paper which was emphasised by Mr. Anfilogoff.

In the same way as polymerisation of unsaturated aliphatic chains yield a type of gum (a parallel which can be found in the changes which take place in isoprene and which do not necessarily involve peroxidation) so may the potential gumming compounds in spirit eventually yield further quantities of gum.

He thought that the question of gumming had a further significance in present-day use which had not hitherto been touched upon. A great amount of work had been done on anti-knock compounds and on methods of obtaining motor spirits which would give the highest useful compression ratio.

If an engine could deal with motor spirit—not kerosine—and there was or could be introduced a series of compounds in that motor spirit which would raise the temperature of combustion, maintaining the pressure more or less the same, then the effect would be produced of burning a heavier compound in a low-pressure internal combustion engine, instead of having to increase the temperature by increasing the pressure as in a Diesel engine.

He thought from the effect that gums had of lowering the H.U.C.R. and so on, that one of the first lines to proceed upon in order to make progress in the direction of burning a heavier oil in a low-pressure internal combustion engine depended on a study of the composition of the gums which were formed.

Mr. G. Calingaert said that the Ethyl Gasoline Corporation has had experience for several years on the correlation between the results of gum tests, the actual amount of gum present in petrol and the tendency of the petrol to develop gum on storage.

Our tests of engine performance on various petrols confirmed the result of similar tests reported at the meeting to the effect that only the gum present in the petrol, and not potential gum, is of any significance in engine performance. However, since the petrol is usually tested before it leaves the refinery and it then remains in storage or transit for some time prior to use, it seems evident that the gumming tendency is of far greater importance than the actual amount of gum present in a freshly prepared product. Investigations of several methods of determining gum involving the protection from contact with oxygen and the use of glass or porcelain dishes indicated that all these methods gave very similar results, corresponding probably quite closely to the actual gum content of the petrol, but giving no information at all regarding its gumming tendency.

Contrarily to some opinions expressed at the meeting, experience extended over a period of years has shown that the copper dish test, if correctly interpreted, may give some very valuable information regarding the gumming tendency of a petrol. It is true that check determinations on the same petrol may vary by as much as 20 per cent. for low values and 100 per cent. or more for high values. But it must be kept in mind that the accuracy of the results of any test need not be greater than the accuracy of correlation between the test and the property it is desired to measure. In this particular case, we, probably do not know within 100 per cent. whether a petrol which gives, say, 30 mmg. copper dish gum is going to give 20 or 50 mmg. gum, say, after a period of storage of six months.

The Ethyl Gasoline Corporation is continually determining the copper dish gum on samples of petrol at the time they leave the refinery. Samples of the petrol, as it is marketed, are also collected at regular intervals at filling station pumps. When the statistical data of the results of the copper dish test of the refinery samples are compared with the copper dish test of the pump samples, it is found that there exists a remarkable correlation between the two sets of data.

When the refinery samples show less than 25 mg., the pump samples seldom run as high as 50 mg. When the refinery samples run over 50 mgr., the pump samples, which are from a few weeks to a few months older, are apt to run as high as 100 mmg. and even higher. This experience seems to indicate that the copper dish test still constitutes a valuable method of correlating the important property of the gumming tendency of a petrol with a fairly rapid laboratory test. Regarding further investigations on the general problem of gum in petrol, there seems to be no immediate need of developing new methods of determining gum. There is, on the

other hand, an urgent need of obtaining data on the two following points :—

1. What is the maximum permissible amount of gum actually present in petrol which will not give rise to operating trouble in the average motor car (or air-craft engine).
2. What is the quantitative or semi-quantitative relationship between the actual tendency of a petrol to develop gum on standing and any accelerated laboratory test such as the copper dish test.

Mr. Calingaert also stated that he had not had time to read the papers exhaustively, but he obtained the impression from a short perusal of Colonel Auld's paper that vapour-phase cracking gave a petrol which was practically free from gum ; that no matter what test was employed and no matter how long the petrol had been stored, the amount of gum was never higher than a few milligrammes. He understood, however, that when Dr. Mardles wanted to make in his laboratory a certain amount of gum he went to a vapour-phase cracked spirit to obtain it. He would like to know if his impression was correct and, if not, where the discrepancy arose.

Mr. E. R. Redgrove asked what, if any, was the similarity between gum formed from petrol and the material which was formed by the oxidation of transformer and lubricating oils.

Mr. E. A. Evans thought the question asked by the last speaker with reference to lubricating oils raised a very important point. So far the discussion had centred upon the estimation of the formation of gums in petrols. Those who are interested in lubricating oils rather than petrols had been led to believe that lubricating oils were solely responsible for the formation of deposits in engines. Colonel Auld stated that the acid test of gum formation was the engine, but the author of the paper appeared fearful to deal with that particular test. Perhaps he had reasons for not doing so, and thought it was as well to leave well alone, but the subject was of importance because technologists in America had stated that they had been taking too much responsibility upon themselves, especially with the higher compression engine, in assuming that the sticking of valves was due to the lubricating oil : it might be due to the gums which, according to his estimation from the figures contained in the papers, amounted to practically an ounce per 100 gallons of petrol. It was suggested by Voorhees and Eisinger that a deposit from the gum formed on the inlet valve ; but Hoffert and Claxton stated the deposit only occurred in the induction tube and was completely burned in the combustion space. It

would be of interest in the engine tests for which Colonel Auld had been responsible if some indication could be given of whether a differentiation had been made between a deposit formed from the petrol and that from the lubricating oil. He had no doubt that the author had closely studied that point and had made some ultimate analyses. It would be of great interest if some information could be given from that point of view.

Lieut.-Col. S. J. M. Auld, in reply, said he agreed with Mr. Anfilogoff when he said that one did not desire to limit the amount of gum in the test to bring it down as low as possible. Concordant results must be obtained, and after that he did not think it mattered what the actual gum content was as long as it could be correlated with engine performance. If some method of standardising engine tests could be obtained he, personally, would be very much happier. With regard to the question that had been asked by Mr. Evans on the subject of engine tests, he thought the only thing was to do a blank, and whatever effect was obtained when using a gum-free spirit in the engine to take that as the answer to the question. In any case, it must be remembered that engine gumming from petrol was all antecedent to the combustion chamber, and therefore not difficult to distinguish from a lubricating oil effect. He did not know whether there was any chemical relationship between the type of material formed from transformer and lubricating oils and petrol, though it seemed likely. It was difficult enough to find one between the products of different cracked petrols, and it became still more difficult the higher one went up the scale. With regard to Mr. Calingaert's question regarding the actual gum content of vapour-phase cracked spirit, the point he had wished to emphasise was that cracked spirits could be made to give a tremendous amount of gum, but if they were properly prepared and refined they could be rendered nearly free of pre-formed gum by any tests at all and so stable that the application of a profound oxidation test would be unfair and misleading. The particular samples he had exhibited had stood up for five and seven months, respectively, with practically no alteration of the gum content. If it was desired to get gum it could be obtained from them by suitable means. The paper was intended to make clear the fact that, in those materials which had particular value as anti-knocks, one should not wish to find out how much gum could be got out of them, but how they would behave in an engine, and then to reproduce tests which would give the same results as the engine. As a measure of pre-formed gum, the flash test described by Dr. Thole and Dr. Norris appeared very commendable, and he would undoubtedly try it out on a laboratory routine. He wished to congratulate Mr. Wagner and Dr. Hyman on what

appeared to be a real advance in explaining the mechanism of gum formation. The hypothesis threw light on a number of otherwise apparently unrelated phenomena, and was of particular interest in explaining the catalytic effect of acids.

Dr. H. Moss, in reply to the question asked with regard to lubricating oil, said that he carried out the tests referred to in the paper, and the engine tests made were not sufficient to produce any fouling of the exhaust valves at all. If a perfectly gum-free petrol was taken and the engine was run long enough sticking up might be obtained due to the lubricating oils; but in all the cases to which the paper referred the duration of the tests was much too short to produce any effect. The fouling was in the inlet passages, on the inlet stems, and just a little on the head of the engine round the inlet valves. The authors attributed all that to the petrol.

The President said it only remained for him to move that a most cordial vote of thanks be passed to the various authors for the interesting papers that had been presented that evening.

The resolution of thanks was carried with acclamation, and the meeting terminated.

The following communication was received from **Mr. T. R. Scott**:

From the data quoted in the papers by Auld, Mardles and Moss, and Wagner and Hyman, it is evident that the mechanism of gumming in petrols is closely related to the mechanism of ageing and of sludge formation in transformer and heavier oils.

In this connection it is significant that Col. Auld refers to a definite induction period during which oxidation is very slow and relatively constant. This induction period is very marked in the sludging characteristics of high-grade transformer oils, and sometimes leads to somewhat false conclusions when deductions are drawn from weight/time characteristics. Similarly, in Table 5 of Col. Auld's paper, sample A judged on the basis of the weight of gum formed during a total period of 72 hours would have different relative values according to whether the initial readings were taken at states corresponding to 0 hours, 48 hours or 144 hours, viz.:—

	Initial State.	*After further 72 hours.*	*Difference.*
(A)	0 hours = 0·0009 mgms.	0·0030 mgms.	0·0021 mgms.
(B)	48 „ = 0·0026 „	0·0033 „	0·0007 „
(C)	144 „ = 0·0039 „	0·0061 „	0·0028 „

If, therefore, a petrol were received for test in a state corresponding to (B) it might be erroneously assumed that although its initial gum content was relatively high its gumming propensity was relatively low. A similar error can occur in judging the effect of the Mercury Vapour Lamp (Table 14, Mardles and Moss) unless care is taken to define the initial state or, as has been done in both instances

quoted, a full time/weight characteristic is given. It appears to be important in the cases of both oil and petrol to commence the characteristics for a time zero—*i.e.*, free from deterioration products. The results discussed above suggest that gum formation follows sludge formation with regard to intermittent action. Tests of electrical conductivity (a.c) have emphasised the intermittent nature of sludge formation for transformer oils (see T. N. Riley: "The Rate of Change of Power Factor on Heating in Air as a Measure of the Quality of Insulating Oils"—Int. Conference on Large Electric Systems, Paris, 1929), and an investigation on petrols on similar lines might bring interesting new data to light.

Another test used with comparative success in the Laboratories of the International Standard Electric Corporation for estimating the amount of deterioration products present and, in certain cases, for forecasting the future characteristics of the oil as ageing proceeds is that of Interfacial Tension by the drop method. This test was suggested by Nuttall (World Power, 1924, **2**, 93), and a convenient semi-routine method of test has been described by Edwards (Journ. Sci. Instruments, 1929, VI., No. 3). In the case of petrols it is probable that it would provide a means of estimating rapidly the gum content in a mode which eliminates many of the disturbing influences recorded in the papers read.

Again, the tentative suggestions offered by Wagner and Hyman regarding the mechanism of gum formation fit very well into any explanation which can be formulated to explain the observed reactions in sludge formation and confirm the view that, from the theoretical point of view, at least much useful data could be obtained by conducting parallel investigations on petrols and heavier oils and contrasting the results obtained.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

THE ONE HUNDRED AND TWENTY-SECOND GENERAL MEETING of the Institution of Petroleum Technologists was held at the Royal Society of Arts, John Street, Adelphi, W.C. 2, on Tuesday, November 12th, 1929, Dr. A. E. Dunstan, President, occupying the Chair.

The Secretary announced that the following nominations had been received for membership of the Institution :—

The undermentioned names were read for the first time :—

Members.—Thomas Michael Hartigan, Percy Norman Hulme, Hugh McCullum MacIntyre, Malcolm Smythe Mainland, Jules Rimbaut, Casimir Zuber, Stanislaw Zuber.

Associate Members.—Christopher Wilfred Percy Edmund Green, Alexander Thomas Spence Simpson.

Transfer to Associate Member.—Horace Vivian Steadman.

Students.—Michael Ross Burnett, Duncan Alexander Cox Dewdney, Reza Khan Fallah, Roy Bruce Finnis, Alan Lancelot Greig, Norman George Gullick, Edward James Stanley Hewitt, George Douglas Hobson, Robert Elliott James, Charles Stirling Lee, Abbas Parkhideh, Paul Pewsner, Abol Hassan Khan Radjy, Alfred Siff, Richard Colin Simmonds, Adrian Jasper Ernest Swann, Theodorus Willem Te Nuyl, Edward Ernest Thorneloe.

The undermentioned names were read for the second time :—

Members.—Carl Franklin Braun, George Walter Furniss, Frank Goldstone, George Hunter, Maung Maung, Thomas Taylor McCreath, F. Georg Mueller, Ernest Arthur Satchell, Howard Theophilus Wright.

Transfer to Member.—Frank Leslie Garton.

Associate Members.—Samuel Charles Anderson, Emanuel Dawidson, Cornelius Antoninius Aloysius Travers Dorans, Arthur George Fenn, William Herbert Harris, Humphrey Harvey Martin, Ernest Patrick Pink, Alexander Reid, Charles Arthur Ross, Edward Kenneth Sargison, Philip Alfred Stiff, Leonard Arthur Toone, George Albert Edward Walling, Jack Watson, Lancelot James Wilson, Alfred Samuel Wolfner.

Transfers to Associate Members.—Oswald Augustine Bell, Neville Aspinall Clegg, Richard James Hayman, Donald Albert Howes, Kenneth Chesterton Johnson, Walter Beveridge Rowntree, Herbert Muggleton Stanley, Ernest George Thorn, George Scott Urquhart, Christopher John Ward, Leslie Newton White, Edward Flasby Whittingdale, Richard Llewelyn Wilson.

Student.—Wilfred Herbert Parsons.

Associates.—Boris Dvorkovitz, Stanley George Green, William Deacon Jarvis, Donal Wheeler O'Brien, Tressilian Walter Ranson, William McKechnie Robson.

Transfer to Associate.—John William Weitz.

The President, in introducing the author, said it would be a work of supererogation to introduce Sir Arnold Wilson to the members of the Institution. His work in connection with the new Housing Scheme for the joint Institutions was very well known, and it was a great pleasure to welcome him on the occasion of his first paper before the Institution. It did rather increase the breadth of one's views as to the definition of a petroleum technologist (which the great founder of the Institution had rather imagined to be restricted to the chemist, the engineer and the geologist), to realise that the time was arriving when the lawyer and the economist would undoubtedly be included in that very highly-sounding and very widely applied term.

The following paper was then read :—

Oil Legislation in Central and South America.

By Lieut.-Col. Sir A. T. Wilson, K.C.I.E., C.S.I., C.M.G., D.S.O. (Member).

The development of the oil industry in South America during the last ten years has been one of the great economic facts of the world. Production has increased from 36,000 tons in 1900 to 742,000 tons in 1910, 24,293,000 tons in 1920, and production for 1930 may reasonably be estimated on the basis of 1928 figures (30,096,000 tons) at 35,000,000. This development has, however, been spread very unequally over the various oil producing countries, as will be seen from the annexed chart.* Venezuelan production has increased steadily—if the word can be properly applied to such

* CHART SHOWING PRODUCTION OF PETROLEUM IN CENTRAL AND SOUTH AMERICA, 1900–1928.

(Thousands of Tons.)

Year.	Peru.	Mexico.	Argentine.	Trinidad.	Venezuela.	Columbia.	Ecuador.	Total.
1900 ..	36	—	—	—	—	—	—	36
1901 ..	37	2	—	—	—	—	—	39
1902 ..	38	6	—	—	—	—	—	44
1903 ..	37	11	—	—	—	—	—	48
1904 ..	46	19	—	—	—	—	—	65
1905 ..	60	38	—	—	—	—	—	98
1906 ..	72	75	—	—	—	—	—	147
1907 ..	101	150	—	—	—	—	—	251
1908 ..	135	587	2	—	—	—	—	724
1909 ..	175	405	3	8	—	—	—	591
1910 ..	177	542	3	20	—	—	—	742
1911 ..	182	1,874	2	40	—	—	—	2,098
1912 ..	233	2,471	7	61	—	—	—	2,772
1913 ..	284	3,835	19	70	—	—	—	4,208
1914 ..	256	3,916	41	89	—	—	—	4,302
1915 ..	332	4,912	76	104	—	—	—	5,424
1916 ..	340	6,052	117	129	—	—	—	6,638
1917 ..	338	8,253	168	222	18	—	—	8,999
1918 ..	338	9,527	194	289	50	—	—	10,398
1919 ..	349	12,996	174	256	64	—	—	13,839
1920 ..	376	23,443	245	150	79	—	—	24,293
1921 ..	493	28,865	257	327	214	—	—	30,156
1922 ..	709	27,205	444	340	329	48	—	29,075
1923 ..	746	22,326	500	424	658	58	—	24,712
1924 ..	1,042	20,820	612	563	1,307	64	—	24,408
1925 ..	1,201	17,348	909	613	2,839	142	23	23,075
1926 ..	1,402	13,549	1,141	725	5,390	906	30	23,143
1927 ..	1,316	9,570	1,240	739	9,019	2,113	76	24,073
1928 ..	1,597	7,485	1,329	1,062	15,667	2,802	154	30,096
Total ..	12,448	226,282	7,483	6,231	35,634	6,133	283	294,494

immense increases in successive years; Colombian production has increased up to a point, represented by the maximum capacity of a single pipe line from a single field, and has stopped there; the production of Argentina has apparently reached its maximum in existing circumstances and shows no tendency to increase; Peru and Ecuador show smaller increases in recent years, due apparently to measures of rationalization usually applied during a period of low prices. In Trinidad production is still increasing. Mexican production has fluctuated sadly, for a variety of causes. The production of other South and Central American countries is negligible.

The object of this paper is primarily to discuss one aspect of the oil industry—namely, the effect thereon of the various legislative systems under which it operates in various countries. When in 1915 the U.S. Bureau of Mines issued in a single volume the Mining Statutes of the various States of the Union, it was stated in the preface that the primary object aimed at was "to aid legislative bodies in framing uniform laws that would be an aid to the mining "industry," in view of the fact that "as a result of defective or indefinite laws the miner, in pursuing his enterprise on the public domain and in attempting to locate and acquire what the Government intended to give him, has been involved in difficulties and in expensive litigation." "Comparisons," wrote John Lydgate, "do oftime great grievance." Burton, in his "Anatomy of Melancholy," described them more tersely as "odious." It is, however, only by comparison that a right judgment can be reached and improvement made possible; and no apology is needed for this attempt to compare, however superficially, the laws under which petroleum may be dealt with in various portions of one of the world's greatest petroliferous areas.

No one will question the postulate that must be made at the beginning—namely, that unsuitable laws may retard, and have in fact retarded, development, to the disadvantage of the parties principally concerned—namely, the country of origin, the shareholders of the producing companies and the consumers, and conversely that good laws will encourage, and have in fact encouraged, petroleum production, with results on the whole advantageous to the said parties.

Let us begin by considering what constitute in practice the salient features of "unsuitable" laws, bearing in mind that we are not considering defects of administration, or possible failures in the administration of justice, nor are we referring to a system of law, such as that contemplated in Argentina, which is avowedly inimical to individual enterprise as such, and in favour of State management and operation. What we have to consider are laws

which purport to encourage private enterprise in development of the industry, whilst regulating it in the public interest, but in fact tend to hamper it.

The first and outstanding difficulty that confronts the student of oil legislation in Central and South America is the complete absence of any sort of uniformity of conception or of treatment of the legal problems involved. This in itself is a serious handicap; assuming that the various countries have, broadly speaking, the same end in view, it is scarcely likely that it can be attained by methods so diverse based on principles so conflicting; certain differences must, of course, exist, but they should be referable to the varying economic circumstances of individual countries concerned, and should even so have common basic principles.

When the American petroleum industry turned its attention south of the Rio Grande, at the beginning of the present century, few Latin American States had laws specifically dealing with petroleum deposits. Such legislation as existed was embraced in the old mining laws dealing with coal and mineral ores. In almost all cases these laws were inherited from the mining laws of the mother country whose underlying principle reserved to the Crown all minerals, whether on the surface or in the subsoil, subject to certain rights granted to the discoverer and exceptions based on the nature of certain deposits. Building stones and clays, for example, were considered to be part of the soil rather than deposits in it. In general coal, not then of large value, was in this class, and the real and assumed relations of coal to other hydrocarbon deposits, such as petroleum, has introduced much confusion into legal interpretation of the older laws throughout Latin America. Either from an anxiety to discard all trace of the monarchical system or from motives of private interest, many of the republics abandoned the principle in favour of another rule widely followed in England and the United States—that the surface owner is also the owner of rights to minerals he may discover in the subsoil. The change, which mostly preceded by several decades the discovery of oil in the United States, was seldom the result of judgment based on long-view national advantage. It derived partly from the desire of states, generally controlled by dictators, to obtain funds from a system of concessions, and partly from the example of the United States, where private ownership had encouraged the rapid and successful exploitation of mineral resources.

The development of the oil industry and its expansion southward forced all the Latin American countries to enact specific legislation. The concession system developed correspondingly. In certain cases concessions were legislatively complete; some required compliance with certain specified laws; while the most vital

aspects of others were dealt with by successive ministerial decrees.

Legislative uniformity as regards both conception and treatment of the problem is entirely lacking, partly because the legal traditions of Central and South America are far from homogeneous, being traceable in the case of the British, Dutch and French colonies to the juridical and constitutional systems of the mother countries, in the case of the Spanish- and Portuguese-speaking republics to the codes imposed by former sovereigns, modified to a greater or less extent by successive constitutional laws whose authors drew their inspiration from the United States of America rather than from Europe.

Nationality Restrictions.

Take, for example, the question of nationality restrictions. In Dutch Guiana, petroleum development is confined entirely to the subjects of the sovereign State; in Brazil effective control must be in the hands of citizens; in British Guiana this stipulation exists, but only affects lands belonging to the state. In some states a proportion of the shares must be offered to local citizens; in others a proportion must be allotted free to the national government. In Guatemala petroleum concessions may not be held by nationals of countries which do not extend similar privileges to Guatemalan citizens.

Ownership of Petroleum Deposits.

In Bolivia, Chile, Colombia, Ecuador, Guatemala and Peru there is a disposition to hold that deposits of petroleum, wherever found, are the property, not of the surface owner, but of the State. In some of these states this is an underlying rule, and in others it applies only to lands granted before or after certain dates. In Brazil the surface owner has full subsoil rights, subject to liability to expropriation. In Guatemala the surface owner has a right to a share of the royalties enjoyed by the State. In Argentina a Bill has passed the Lower House which declares that all petroleum deposits are national property and authorises the expropriation of all foreign producing companies, though without as yet providing the requisite funds for their purchase. In Chile the power of the executive to grant petroleum concessions has been suspended and replaced by legislation which empowers the executive itself to undertake exploration for oil at a cost not exceeding ten million pesos. In Mexico the Central Government now retains the ownership of mineral resources. Formerly it conceded the landowner the rights to coal and oil in his land, but reclaimed these in 1917 with effects temporarily disastrous alike to the oil industry and to the

country's finances. The major difficulty here arose over the status of these minerals in lands to which title had passed from the Government prior to 1917, but as to which there had been neither development nor erection of separate title.

Domicile of Concessionnaire Companies.

A like diversity prevails in the regulations governing the status and domicile of the producing company. In Trinidad, British Guiana, Argentina, Bolivia and Brazil the company must have a domicile within the country's domain. In Ecuador, if the lessee is a foreign company, the manager must have adequate powers. In Colombia a distinction has been drawn between exploration and exploitation; for the former purpose a local domicile is unnecessary. The laws of this country are now in process of revision, and in the Petroleum Bill now before the Assembly at Bogota this distinction is no longer made. In a few countries the point is not covered by specific regulations.

Many states have an overriding clause which provides for the forfeiture of concessions if they are obtained by, or transferred or mortgaged to, a foreign Government, or if a foreign Government is admitted as a partner or shareholder. The effect of these clauses is as doubtful as their origin is, in many cases, obscure; the precise language employed varies in each country and is susceptible of various interpretations, none of which can be regarded as authoritative, as no test case has been brought in any Supreme Court. Their existence, however, in certain States tends to exclude certain companies in which Governments have a shareholding or other interest. Such companies exist in England, France, Italy, Spain and elsewhere, and their number is likely to increase.

Other Provisions.

It would serve no useful purpose here to compare in detail the differences between the legislation provisions in different countries relating to subsidiary matters such as (to quote only a few):—

(1) The period for which a concession may be granted and that allowed for exploration;
(2) The royalty payable and how calculated;
(3) The legal proportion, if any, of local staff to be employed;
(4) The area of concessions, etc., for (*a*) exploration; (*b*) exploitation;
(5) Refining obligations and measures to be taken to supply local needs;
(6) Local prohibitions relating to areas adjoining frontiers, the seaboard, ownership of river beds, etc.

It is enough to say that they vary greatly and that the differences are seldom to be explained by local exigencies. Indeed, it would be the task of an encyclopædist to survey the entire body of disparities in Latin American oil legislation, for it is a maze of bewildering diversity. Laws have grown partly out of purely fortuitous circumstances, as in Argentina, where the legislation owes some of its inspiration to a strong radical party, recruited largely from recent immigrants from Europe, and partly out of a desire to avoid the political inconveniences suffered in Mexico and elsewhere by the sudden growth of a highly organized industry in a pastoral and agricultural economy.

In the absence of decided cases, the law in several Latin American States is doubtful with respect to the right of the surface owner to draw oil and gas from adjacent subsoil in another's possession. English mining law gives the right to the discoverer of a vein of lead to follow the vein beneath the property of others and to remove the ore. So long as mining was carried out on a small scale, this ancient principle, known as the Apex Law, which was merely confirmed by Edward I. in 1287, encouraged mining by guaranteeing to the discoverer the fruits of his enterprise. As deep mining became common, however, this guarantee proved unworkable, and the principle of vertical limitation was adopted. It is enforced to-day in the coal industry. In the United States a succession of legal decisions has established the principle that oil or gas in the earth belongs to that surface owner who captures it and reduces it to possession, this rule having been derived from an older one covering wild game. Surface ownership, therefore, confers the right to drill and produce oil and gas from the owner's or from adjacent properties; offsetting thus becomes the only remedy. Whether this principle would be maintained in the courts of certain Latin American countries, where the principle of vertical limitation is enforced, is not certain.

From the foregoing very brief summary, which might be almost indefinitely expanded, it will be seen that no comprehensive statement can be made as to Latin American petroleum legislation. It is, however, possible to offer some general observations on the origin and present trend of the laws both existing and in contemplation directly affecting petroleum. In the first place, with very few exceptions they are, as has already been shown, to a greater or less extent influenced by the old Spanish mining laws, which dealt with mineral ores, and by the reaction against the monarchy and everything connected with it that took place during and after the Revolutionary period. To this period, may, in several instances, be traced the clauses against foreign government participation in concessionnaire companies.

Secondly, there are traces of the strong diplomatic influences exerted by Washington in 1919, at a time when the view was widely held in the U.S.A. that its own oil measures were within measurable distance of depletion, if not of exhaustion, and that outside sources of supply would become vital to the national welfare in the near future.

Thirdly, and at the moment predominantly, existing legislation is affected by the somewhat violent national reactions directly provoked by the activities, both diplomatic and commercial, of the post-war period to which reference has just been made. Administrative measures born in fear and nursed in an atmosphere of misapprehension and distrust seldom deserve a permanent place among the Statutes of a nation, and are almost invariably harmful to the economic welfare of the country immediately concerned. The class of legislation which we are considering is no exception to this rule, and it bears the marks of its origin. With a few notable exceptions, it is based on the following assumptions, which are, unfortunately, not peculiar to Latin America :—

(1) That petroleum deposits in any given country are the absolute property of the inhabitants, to be utilised, or not, solely in their own interests, without reference to the needs of the world at large.

(2) That the investment in an undeveloped country of large amounts of foreign capital is a potential menace to its independence, whether political or economic; that this applies in a peculiar degree to the capital required for petroleum development. Special enactments are therefore necessary to prescribe the conditions under which such foreign capital investments may be made.

(3) That there is a probability of a world shortage of petroleum products in the comparatively near future, and that each government has the duty in the vital interests of its nationals, and *therefore the right*, to take steps to conserve its own reputed deposits of petroleum for the use of future generations.

(4) That exports of petroleum, whether crude or refined, constitute a drain on the natural resources of the country concerned, without adequate counter-balancing advantages, since petroleum deposits, however vast, are limited.[1]

Adequately to discuss these postulates would involve reference to considerations which scarcely fall within the scope of this journal,

[1] See review by Sir Richard Barnett of Filhol's *Législation Mondiale du Pétrole*, 1929; *J. Inst. Petr. Tech.* 1929, **15** (74), 404.

though many of its readers have enjoyed exceptional facilities for observing the operation of enactments based thereon, and are in a high degree qualified to express a reasoned opinion on the cogency of the arguments which they imply and on the practical results that have ensued from their acceptance as axioms of political economic science in Latin America. It is not practicable to do more than offer an outline of what may be termed "the world-outlook," as it affects each of the assumptions outlined above.

We will consider first the assumption that petroleum deposits, in common with other sources of raw material, are the absolute property of the territorial authority, without reference to the needs of the rest of the world.

International jurisprudence, whilst recognising specifically the absolute sovereignty of the territorial authority within its borders, condemns its exercise in a manner needlessly detrimental to others. A host of international organisations have grown up in the last century to give effect to this principle; the conduct by each nation within its own borders and under its own laws of postal, telegraphic, radio and sanitary services is, to a larger extent than is generally realised, subject to international agreements. The hours and conditions of labour, the load line of sea-going steamers, privileges of copyright, the minutiæ of veterinary inspection and agricultural defence are only a very few of many matters in which Governments have long ago voluntarily accepted restrictions on the exercise of their sovereignty and have undertaken obligations to their neighbours and to the world at large. More recently, in 1921, at Barcelona, under the auspices of the League of Nations, an International Convention was conducted dealing with problems of transit: the signatories mutually agreed to forego the privilege of taxing goods in transit through their territories to other countries, and generally accepted the principle that international rivers—*i.e.*, navigable rivers, serving more than one territory—must not be subject to the jurisdiction of any one nation. The list might be extended indefinitely and would be found to include almost every form of human activity.

It is not unreasonable to suggest that the time is ripe for international recognition of the mutual and increasing dependence of all countries on each other for raw materials, and for an attempt to translate the necessary implications of such recognition into a form of agreement.

"Private property," wrote Mill in his book on "Distribution"[1]: "in every defence of it, is supposed to mean the guarantee to

[1] I quote from the 7th Edition, the last to be revised by Mill, published in 1871.

individuals of the fruits of their own labour and abstinence. The guarantee to them of the fruits of the labour and abstinence of others, transmitted to them without any merit or exertion of their own, is not of the essence of the institution. . . . To judge of the final destination of the institution of property, we must suppose everything rectified which causes the institution to work in a manner opposed to that equitable principle of proportion between remuneration and exertion, on which, in every indication of it that will bear the light, it is assumed to be grounded."

Had Mill been dealing with the rights of States in relation to the world and to each other and not with those of individuals, it can scarcely be doubted that he would have demanded a revision of the assumptions on which national policy is now based so far as concerns the control of raw materials and especially of mineral resources.

The need for such a revision is implicit in almost every page of the Resolutions passed by the World Economic Conference at Geneva in May, 1927. This Conference, like that of 1928 at Habana, was, it is true, silent on the question of petroleum, to which only incidental references were made: but the *argumentum ab silentio*, always weak, is wholly inapplicable. One resolution, however, dealing with the economic and fiscal treatment of nationals of one country admitted to settle in the territory of another, has a direct application to the oil industry. It reads as follows: "Recommends a diplomatic conference for the purpose of drawing up an international convention for the abolition of unjust distinctions. . . . Meanwhile bilateral agreements providing for equitable reciprocity . . . might effect a valuable improvement."

This resolution is a substantial endorsement of the policy embodied in the Mineral Leasing Act passed by the U.S. Congress in 1920, and deserves special attention at the hands of those Governments who have not yet found themselves able to give effect in the sphere of petroleum legislation, to the policy unanimously endorsed by their representatives at Geneva.[1]

The second thesis, viz., that the investment of foreign capital is a potential menace and must be rigorously controlled, is perhaps more difficult to deal with than the propositions dealt with above. It is a thesis which is from time to time advanced in this country, when, for example, American capital seeks an outlet in the electrical or automobile industry, or when the German chemical industry extends its activities across the Channel. It is a cry frequently raised in the U.S.A., both in regard to petroleum and other companies. The course of wisdom is in this matter the middle course.

[1] Holland was in 1928 recognised by the U.S.A. as a reciprocating country for the purposes of the Act.

On the one hand, each nation must maintain sufficient control over its own resources to hold its own in competition with other races: on the other hand, it must do so compatibly with the general welfare. In principle it is obviously undesirable to limit the inflow of foreign capital into Latin American States, especially at a time when it is urgently needed and is scarce and dear. Further, few Latin American countries can afford to discriminate against foreign capital, still less against capital from the U.S.A. to which country the bulk of their exports is destined (except in the case of Argentina).

An invested capital of approximately £2,000 is necessary to employ a man permanently in industry in this country; perhaps half that sum is necessary in Latin America, where the climate and the ease with which food and shelter can be obtained has resulted in a somewhat lower wage level. But the amount required is sufficiently large to demonstrate the unwisdom of limiting in ordinary circumstances the influx of capital.

On the other hand, high American tariffs are a source of grievance to Latin American statesmen. They have not forgotten that the third of President Wilson's fourteen points was: "The removal, as far as possible, of all economic barriers and the establishment of an equality of trade conditions among all the nations consenting to the peace and associating themselves for its maintenance."

They believe, too, that the recent purchases by U.S. interests of business concerns in Latin America hitherto controlled by European capital are organised and part of a carefully designed plan. The object is not so much dividends as trade, and the countries concerned do not desire that form of economic servitude that is liable to supervene when their trade is with one country to the mutual exclusion of others. Whilst the free international movement of capital is on broad economic grounds desirable, there are equally strong grounds for making exceptions in the case of certain industries. Some institutions such as local banks, trunk railways and internal shipping lines, the control of which is threatened, have a value to the country concerned[1] far greater than their possible dividend value to stockholders.

Others, such as telephone and radio companies and concerns which are solely occupied in the export of raw material, fall into a different category: it is natural and, in the present state of development of Latin America, inevitable that the capital and the commercial control should be foreign.

[1] An interesting example of the practical recognition of this fact is the recent decision of the stockholders of the Buenos Ayres and Pacific Railway to take steps to preclude the possibility of foreign stockholders other than Argentine nationals obtaining control of the Company.

In point of fact the statistics of foreign investments in the ten States of South America give little cause for alarm. In 1928 United States investments were estimated at rather over 2,000 million dollars as against 4,000 million dollars from Great Britain and 2,000 million dollars from other countries. Public loans in the ten countries total rather over 1,500 million dollars. It is clear that, generally speaking, Latin American borrowings are well spread, and the prohibition of armed force for the recovery of contract debts, which Mr. Choate thought was worth all the trouble and labour of the second Hague Conference, should relieve the borrowing States of any serious anxiety. It is from their point of view more important that their exports, and therefore their imports, should be more widely distributed than at present. It is bad to borrow exclusively from one country: it is worse to trade with one country only, and worse still if that country is also the principal lender.

Generally speaking, however, the facts suggest that the political economic danger to any Latin American State from an influx of foreign capital is negligible, and that within the lifetime of men now living they will have ceased, like the U.S.A., to borrow largely abroad and will become financially self-sufficient.

We will now turn to the third assumption—viz., that there is a probability of a world shortage of petroleum and that each nation should therefore conserve its own deposits.

To begin with, it is clear that the principle of national conservation of mineral resources cannot be confined to petroleum, and if it is exercised in regard thereto other nations who need it will be tempted to retaliate. There are several raw materials of which one nation or a group of nations has a virtual monopoly to-day.

If the nations of the world were to initiate a series of export controls based on the need for, or in retaliation for, a policy of national conservation of raw materials, the prospects of civilisation would be poor indeed.

No reliable estimate has yet been or can possibly be made in the near future of the oil resources of the world. Such estimates as have been published have been promptly repudiated by publicists and falsified in due course by experience. The world's output to-day is far below the capacity of actual producing wells. For our purposes, however, we may take the estimates of the U.S. Geological Survey as being the best available basis for dispassionate consideration. These estimates[1] credit the world with some

[1] Power Resources of the World . . . World Power Conference, London, 1929.

43,000 million barrels, of which the U.S.A. holds about one-sixth and Latin America about one-third, fairly equally distributed between the Central American States and those of the Northern and Southern parts of South America respectively.

When it is remembered that the total population of Latin America from Mexico to Tierra del Fuego inclusive is under rather than over 90 millions as compared with 118 millions of the U.S.A., and that the consumption of petroleum products of Latin America to-day per head is[1] estimated to average scarcely one-twentieth of the corresponding figure for the U.S.A., it is clear that no group of people has less reason to fear a shortage of petroleum than the Spanish and Portuguese-speaking communities of the New World. It must, however, be borne in mind that Nature in Latin America, as elsewhere, has not endowed all areas equally lavishly : against the rich deposits of Mexico must be set the geologically unpromising neck of land which runs from its southern boundary as far as Colombia. The Atlantic Coast of South America from the Orinoco to Comodoro Rivadavia has not yet rewarded the patient labour of prospectors.

ESTIMATED CONSUMPTION OF PETROLEUM PRODUCTS PER HEAD OF POPULATION IN CERTAIN COUNTRIES IN 1928.

Country.	Population. (millions).	Estimated Consumption Imp. Gallons (millions).	Per Capita Consumption Imp. Gallons.
United States	118	26,912	220
United Kingdom ..	45	1,640	36
Argentina	10	624	60
Chile	4	171	43
Peru	5	54	10
Colombia	8	65	8
Bolivia	3	7	3
Brazil	36	103	2

The following table shows the amounts of crude petroleum produced in Central and South American countries in the last three years. The total production amounts to over thirty million tons for 1928, as against an estimated consumption in the same year of some five million tons.

[1] Liquid products only, excluding asphalt, wax, etc. Bunkers have been excluded as far as possible. Large quantities of petroleum products are used as fuel in Argentina and Chile, *e.g.*, by railways and nitrate oficinas.

(Thousands of Tons).

Producing Country.	1926.	1927.	1928.
Central America			
Mexico	13,549	9,570	7,485
Trinidad	725	739	1,062
South America.			
Venezuela	5,390	9,019	15,667
Colombia	906	2,113	2,802
Peru	1,402	1,316	1,597
Argentina	1,141	1,240	1,329
Ecuador	30	76	154
Total	23,143	24,073	30,096

If the Latin American States could ensure to each other in perpetuity the preferential use of their respective mineral resources, they could afford, thereafter, to open their doors to foreign capitalists who are ready to spend the great sums necessary to prove the existence or otherwise of oil in these almost always forbidding and often remote regions.

In any case it may be doubted whether human ingenuity and foresight cannot be better employed than in legislating here and now for shortage of petroleum which is based on the assumption that neither new sources of power nor better means of discovering and utilising petroleum than we now possess will be available during the present century. All the petroleum produced to date is less than two-thirds of a cubic mile in bulk: there is much more than that somewhere.

Henry Wrigley in 1882 announced the impending exhaustion of the Pennsylvania fields, then producing 25 million barrels a year. Charles Ashburner, in 1886, followed suit, and in 1891 the anticipated decline of this field began, but was more than counterbalanced by increasing production elsewhere. In 1908 David Day, whilst urging measures of conservation, estimated that reserves were adequate for from 50 to 100 years on the basis of existing production—viz., 180 million barrels a year. He was followed in 1915 by Ralph Arnold, who estimated future potential production from U.S.A. fields at 5¾ thousand million barrels, as against 3¼ thousand million barrels produced up to that date; yet by the end of 1927 total U.S.A. production had exceeded his total estimate of available reserves by more than a thousand million barrels.

Again, early in 1919, David White estimated that less than 7 thousand million barrels were still contained in the ground and recoverable by ordinary methods of production. At this date the annual production had reached 350 million barrels, and the cry that the U.S.A. had no more petroleum than would meet its needs

for 20 years resounded through the world and had its diplomatic repercussions, as already stated, in every country in South America and in many others.

A further estimate, by the U.S. Geological Survey, in 1922, gave a total reserve of a little over nine thousand million barrels. The latest estimate, in 1925, by a committee of the American Petroleum Institute of petroleum reserves of proven areas in the U.S.A., totals over 26 thousand million barrels; it was supplemented by the statements that whereas about 3 million acres of proven and producing lands existed in 1925, there remained over a thousand million acres in which oil might be found.

The possibility of an increase in production costs during the next decade seems remote, but it is sufficient to cause the leading oil producers to look abroad for fresh sources of flush supply.

Nevertheless, the theory of an approaching world shortage of petroleum, whether in six or in 60 years, has no support within the industry, though it still provides a theme for industrious journalists.

As to the *fourth* assumption, that exports of petroleum constitute a drain on the natural resources of the country concerned, without adequate counter-balancing advantages, the following quotation from Sir John Cadman's speech to the American Petroleum Institute on December 6th is very much to the point:—

"So soon as a nation's oil resources are discovered, their forces tamed and harnessed, and the process of extraction reduced to a matter of routine, that nation is within her rights in conserving an ample measure of these resources for the greater safety of her realm. . . . In a country of small consumptive power the mere possession of natural oil is of itself an asset only in so far as a whole complex of external conditions makes it so. Without hundreds of investors willing to lose four times out of five in the hope that at the fifth they will make good their losses; without the instruction of a whole faculty of technical resource, founded and developed in other countries—or, it may be, in another hemisphere; without an army of pioneers who have adjusted the needs of man to the character of the product and vice versa; without a network of distributive systems having been traced upon the face of the globe—without every one of these things, the oil deposits, priceless as they are potentially, might just as well have been deeply buried in the moon."

More than one attempt has been made in recent years to secure collective consideration of economic problems by the U.S.A. and Latin American States.

At the first session of the American Institute of International Law held at Washington in 1916 the jurists representing the

American republics adopted a declaration of the rights and duties of nations, Article II. of which reads as follows:—

> "Every nation has the right to independence in the sense that it has a right to the pursuit of happiness and is free to develop itself without interference or control from other States, *provided that in so doing it does not interfere with or violate the rights of other States.*"

This, the first official recognition of what Herbert Spencer terms "universalistic hedonism" as an international principle,[1] was as far as the jurists were prepared to go in 1916, but at Habana, in 1928, at the Sixth International Conference of American States (generally known as the Pan-American Conference), the Governing Board recommended the preparation of projects of uniform legislation on

(*a*) Commercial law and other branches of legislation in which uniformity is possible and desirable.

. . . . . .

(*c*) Principles to which the juridical status of companies in a foreign State should be adjusted, with a view to securing uniform standards.

A resolution was passed organising three permanent committees at Rio de Janeiro, Montevideo and Habana respectively, to deal systematically with these and other matters[2] with a view to inclusion in a future international conference. The Committee with headquarters at Habana was constituted to undertake the study of comparative legislation and uniformity of legislation. Its functions were defined as follows:—

(*a*) To present to the governments a list of the subjects susceptible of codification and uniformity of legislation, including those definitely subject to regulation and formulation, and those which international experience and new principles and aspirations of justice indicate require prudent juridical development. The presentation of this list shall be for the purpose of obtaining from the governments a statement as to the subjects which in their opinion might be the object of study as a basis of the formulation of conventional regulations or of organic declarations.

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[1] The reference to the right to the pursuit of happiness is, of course, copied from the Declaration by the Representatives of the U.S.A. in Congress on July 4th, 1776.

[2] International Conciliation, No. 241, June, 1928, published by Carnegie Endowment for International Peace.

(*b*) To classify, on the basis of the aforesaid list and of the replies of the governments, the subject matter in the following manner: (1) subjects which are susceptible to codification because they have the unanimous consent of the governments; (2) subjects which are susceptible of being proposed as subject to codification because, while not unanimously supported, they represent the predominant opinion of the governments; (3) subjects with respect to which there is no predominant opinion in favour of immediate regulation.

(*c*) To present the foregoing classification to the governments in order to ascertain their general views with respect to the manner in which the juridical problems of codifiable subjects can be brought up and resolved as well as all information and juridical, legal, political, diplomatic and other antecedents which might lead to a complete understanding.

(*d*) To request and obtain from the national societies of international law their scientific opinion and their general views regarding the regulation and formulation of the juridical questions which are the objects of these committees.

(*e*) To organise all the foregoing material and remit it together with drafts of projects to the Pan American Union, which shall submit them to the scientific examination of the Executive Council of the American Institute of International Law so that it may make a technical study of said drafts and present its conclusions and formulas, with full explanations in a report on the subject.

A gallant attempt was indeed made, at the opening of the Conference, by Dr. Pueyrredon, Chairman of the Argentina delegation, to force the pace and to bring economic questions within the direct purview of the Pan American Union.

The Preamble to the Convention placed on record the signatories as "desirous of promoting efficaciously the harmonious development of their economic interests," thus vesting the Union with an economic function. Dr. Pueyrredon desired to add the following clause:—

"Economic co-operation being an essential factor in the realisation of these purposes, the signatory States tend to the suppression of unjust obstacles and excessive artificial barriers which may hinder natural interchange or restrict the liberty of commerce between the nations of America, without according privileges or creating exclusions."

His views were not accepted and he resigned his position at the Conference: the Union decided that economic questions were domestic in their nature and beyond its competence. There for the moment, the matter rests, but not, it is to be hoped, for long.

Article II. of the Declaration of the Rights and Duties of Nations referred to above is not unconditional. To quote Elihu Root, speaking in 1904[1]:—

> "The formal rules of international law are but declarations of what is just and right in the generality of cases. But where the application of such a general rule would impair just rights . . . or would injuriously affect the general interests of mankind, it has always been the practice of civilised nations to deny the application of the formal rule and to compel conformity to the principles of justice upon which all rules depend . . . . All sovereignty is held subject to limitations in its exercise arising from the just interests of other nations."

The following quotation from Captain A. T. Mahan[2] is also pertinent:—

> "The claim of an indigenous population to retain indefinitely control of territory depends not upon a natural right, but upon political fitness, shown in the political work of governing, administering and developing, in such manner as to ensure the natural rights of the world at large that such resources should not be left idle, but be utilised for the general good."

The reader who has the patience to wade through the foregoing somewhat lengthy disquisition will have observed that:—

(1) The diversity alike of principle and practice in the oil laws of various nations is such as to hamper development and is contrary to the interests of the nations concerned and of the world at large.

(2) Economic questions, though not included, are not specifically excluded from the consideration of the Pan American Union.

(3) The permanent committees set up by the resolution of the Sixth Pan American Conference constitute the nucleus of an organisation already empowered to study comparative legislation with a view to the encouragement of uniformity.

Surely the time is ripe for an attempt, during the next few years, to elucidate this most complicated problem, in the interests of international amity and world commerce. "*There is a tide in the affairs of men, which, taken at the flood, leads on to fortune.*" Over-

[1] Addresses on International Subjects, Root, 1916.
[2] The Problem of Asia, A. T. Mahan, 1900.

production of petroleum in the U.S.A. and elsewhere has caused a temporary slackening of demand for the immediate development of the Latin American oil-fields. Mr. Hoover's good-will tour has not been without its effect on American relations and a concerted effort is being made by the principal oil groups, British, Dutch and American, to reach an agreement on general principles which, whilst leaving each group with the fullest measure of freedom, will prevent, in future, periods of scarcity and high prices alternating with excess production and cut-throat competition for markets.

Unlike many great industries, the oil industry is not controlled by financiers, though it occasionally suffers from their intervention ; it is master of its own destiny and its captains are not without souls.

So far from being, as is sometimes represented, a disturbing factor in international gatherings, the representatives of the petroleum industry have, both during and after the Great War, consistently striven to find, and when found to follow, a course consistent alike with their duties to their shareholders, to the nation to which they owe allegiance and to the even wider interests of the world.

History has her crowns in store for the unpretending, and the time is not far distant when the services rendered to international peace and civilisation by the steady efforts of commercial organisations dealing with the world's oil supplies under their present leaders, will be recognised by the governments of the world.

If any progress is to be made on the lines suggested in the foregoing pages, it is clear that the preliminary work of collecting material and of tentative codification, step by step, subject by subject, must be accomplished in the first instance by organisations within the oil industry itself.[1]

"The toad beneath the harrow knows, exactly where each pin-prick goes,
"The butterfly upon the road, preaches contentment to the toad."

Government offices are full of butterflies in this sense, and it is in any case impracticable for governments to do the threshing out of questions necessary to elucidate the facts relevant to a great and complicated industry.

The process of elucidation and subsequently of codification, must commence with private initiative, though it can only be brought to a successful conclusion by government sanction.

The next step is to present the material, properly marshalled, to the appropriate authority—in this case the permanent committee at Habana of the Pan American Union.

[1] The first conference on International Peace at The Hague would have been a complete failure, said Elihu Root, if it had not been for the accomplished work of the Institut de Droit International.

The lead up to this point might well be taken by the American Petroleum Institute, with whom, if invited, representatives of the petroleum industry in Europe would gladly co-operate.

The third step is to draft a declaration of general principles, and so far as may be, a model code of regulations in conformity therewith. The fourth and last step is to secure its acceptance by the States concerned.

The last two stages can only be traversed with the co-operation of the United States Government, whose assistance, if lent, would go far to ensure success.

Apart from the very numerous questions of principle and detail, both of legislation and practice, indicated above, the first aim and object of codification of petroleum laws in Latin America, which must, if it is to be of use, include a measure of rationalization, should be to introduce (without retrospective effect) the principle of unit development. By this term is meant unified control of single geological structures, or so-called "pools." Wherever commercial foresight or good fortune has made the adoption of this principle possible, it has had the following results :—[1]

(1) Increase and prolonged supplies, which can be regulated to meet supply and demand.

(2) Lower costs and a minimum of waste of gas.

(3) More oil recovered, *i.e.*, less left irretrievably in the earth, as gas and air lifts, repressuring and other systems can be applied at an early stage.

(4) Effective control of water.

(5) Resulting from the above, steady prices; creation of fresh wealth, steady dividends to shareholders, and royalties to governments and other royalty owners.

Further points of international importance are :—

(1) An international convention to regulate pipe-lines from one territory through a second to the sea, on the basis of the International Convention of Barcelona on Transit (1921).

(2) Income-tax questions—already under examination by the League of Nations.

(3) Import and export duties on petroleum products crude and refined, and on material for petroleum development.

The goal is distant, but it is worth pursuing, and there is no reason to think that the Latin American States will view the attempt with disfavour or even with suspicion, for the decision

[1] See especially paper by H. L. Doherty, American Inst. of Oil Engineers, 1925; and ibid, I. L. Dunn and J. O. Lewis, 1926.

will be in their hands, and in theirs alone. Co-operation between national and international forces there must be, if civilisation is not to founder, and in the form of codification suggested there is room for the fullest measure of elasticity, which will take into account the varying economic ambitions, as well as needs, of the interested States. It is only through nation working with nation, forgetting national boundaries, that we shall ultimately attain to the only possible solution, as the result of which, the mineral resources of the world will be placed on equal terms at the disposal of all humanity.

DISCUSSION.

The President said the members of the Institution had had an opportunity of listening to an aspect of the petroleum industry which had never been presented to them before, and all present must realise that more and more the Institution had to depend on applied economics, and that under the great umbrella of petroleum technology, economics and the legal side of the profession, both found their place. He personally had neither the knowledge nor the ability to criticise, or even to discuss, the paper; but among the members was Sir Frederick Black, to whom the Institution had in the past been inclined to listen on matters economic, and no doubt he would be happy to open the discussion.

Sir Frederick W. Black said he thought that many of those present, probably most of them, would divide themselves over the paper just read into two groups: those whom the shoe had pinched in their work in some of the countries mentioned in the paper, in South America and elsewhere, and others who had not been directly pinched, as it were, but who took an interest in those broad questions of economics and oil legislation and international ethics. He had spoken to one or two of his friends who had been in America on oilfields—to be discreet, somewhere between Hudson Bay on the north and Cape Horn on the south—and they said they had got to be friends with the government under which they lived, and therefore had to be very discreet in what they said. He thought the author must have recognised something of that sort when he wrote in his paper: "The toad beneath the harrow knows exactly where each pinprick goes." Some of those present had been in the position of the toad; and the toad, he believed, was not particularly vocal under the pinprick, but sat down under it pretty quietly. There was another interesting character introduced: "The butterfly upon the road preaches contentment to the toad"; and then he read a sentence

full of interest to him, pregnant with meaning, because he had, in his time, for his sins or for other reasons, been a Government official. He referred to the sentence: "Government offices are full of butterflies." He had suggested privately to the author that as that sentence followed immediately upon the toad-butterfly illustrations, it was not likely to be misunderstood. It merely meant that the Government official liked a quiet and contented life, and did not stir up strife unnecessarily. But he wished also to suggest that if that sentence got quoted away from its context, and went forth to the world as meaning that Sir Arnold Wilson had said that Government offices were full of butterflies, he might then be in for a bit of criticism. However, Sir Arnold had held high office himself, and was well known as anything but a "butterfly."

He hoped that, in spite of what he had said, no one would be deterred from saying something about his own experiences, and giving a few concrete illustrations that would be useful, and that the dictates of discretion would also to some extent be regarded from the point of view of the American admiral who said: "There's no use being an American and an admiral if one may not sometimes be a little bit indiscreet."

He heartily agreed with what the President had said as to the value of Sir Arnold Wilson's paper on oil economics and quasi-legal questions, and with what the author had said as to the importance to everybody—the commercial directors of the company and the individual technologists on the spot—as to whether local legal conditions and administration were good and sound in principle, or otherwise. With regard to some of the unsound legislation referred to in the paper, he thought these were golden words of wisdom which the author used about "the middle course being the right and proper one." He agreed with the author as to defects at present existing and also with the methods advocated of commercial initiative, conferences so to bring about improvements. The author, in drawing attention to some of the principles which had been adopted, added: "With a few notable exceptions, one policy is based on the following assumptions, which are, unfortunately, not peculiar to Latin America," after which followed four propositions. Stated as those principles were, he (the speaker) agreed that one might find a good deal of objection to the application of some of them. He thought, however, he was right in assuming that Sir Arnold was not wholly condemning those particular principles, but was objecting to extreme and unreasonable application of them. Carefully examined from all points of view, and to find the middle course recommended by the author, he thought it must be said that one could not apply a

wholesale condemnation to all those points. For example: "That petroleum deposits in any given country are the absolute property of the inhabitants, to be utilised, or not, solely in their own interests, without reference to the needs of the world at large." It was always difficult, even in the relations of one individual to another, to apply those principles that the philosophers call altruism or "universalistic hedonism." It was certainly an extremely difficult thing for a country to say, without many reservations to meet local circumstances, that it regarded its natural resources as not only for its own use, and to make a good commercial exchange with other countries, but also as held in trusteeship for the general welfare of mankind. That was an ideal state of things at which few nations, if any, had yet arrived, and supposing that a nation did not apply altruistic principles, what was the coercive or persuasive force that was going to compel it to do so? Supposing, for example, that a nation had coal mines, and had enough coal for its own services. Supposing, further, that that country was situate somewhere in a cold region, where coal was of very vital necessity, and supposing that it had a good exportable surplus, and made a decent commercial profit on sending its coal out all over the world, and then the supply began to give out. What was the nation to do then? Should it continue to export a certain proportion of its output and allow its own people to shiver, or allow its own industries to suffer? The same sort of consideration arose on the author's third point: "That there is a probability of a world shortage of petroleum products in the comparatively near future, and that each Government has the duty in the vital interests of its nationals, and therefore the right, to take steps to conserve its own reputed deposits of petroleum for the use of future generations." One came up against some extremely difficult questions when dealing with such a proposition as that. Many people would hold that a nation surely had the right to take steps to conserve its own reputed deposits of petroleum for special services of its own. He thought the author rather begged the question by putting in the words "for future generations." In dealing with that kind of question one came up against some of the problems which arose in the war-time, which were called the problems of priority, when it had been said that priority A covered the things that were of vital necessity, priority B things that were of comfort and convenience if there were enough to go round, and priority C luxuries. Applying that for the moment to oil, and taking the figures given by the author in his paper of the consumption per head in different countries, he thought the author gave the United States figure as 226 gallons per head per annum, and the British figure at 36. How could those figures be divided

into any such classification of priority in each country or between several countries competing for supplies, if the requirements of one or more countries had to be met in case of shortage from other than the consuming countries? One could imagine a country with petroleum resources saying: "Yes, if we have a good supply or an exportable surplus we are willing to supply petroleum at a price for export up to a certain limit; but we are going to conserve supplies for our own requirements at home and for our industries and for national defence; but why should we supply oil to somebody else of which we have a vital need at home, either immediately or prospectively in the near future? Why in such circumstances should we permit our oil to be used for purposes of luxury?" He was arguing this question merely as illustrating some of the complexities of the application of equitable broad principles as between one nation and another in regard to working and distributing oils or minerals generally. He agreed with Sir Arnold Wilson that in the present abundance of oil the question of obtaining supplies beyond present oilfields was not as acute as it might be at some future time. He also agreed with the broad general principle that the world's resources of minerals ought to be distributed wisely for the general good as far as that is anyway possible, either by normal commercial competition or by special international agreements in special cases.

With regard to the question of foreign capital, he was very strongly with the author. It did seem an unreasonable thing that a country should object, if it wished its resources exploited, to a reasonable amount of foreign capital coming in; but then, again, there were certain dangers. Small countries, in particular, were peculiarly susceptible to the possibility that big capitalists from other countries might come in and exploit the resources of the country for their own profit, and tear all the oil out of the land and leave the country bereft of some of its most valuable resources to go back to pastoral and agricultural conditions. He thought a country was undoubtedly justified in protecting itself against extreme or unreasonable exploitation.

For example, on the question of national defence, a country might well have no objection to capital coming in from elsewhere to develop its resources, but yet not wish to find that the people who wanted to put their capital in might take the line that the supplies were not near enough to the market to be fully or effectively developed until a later date. That attitude might be perfectly sound from a commercial point of view; but the position of the country possessing those resources and wishing to have them developed more expeditiously up to a reasonable point must be

considered. There might come some great emergency, there might be a question of war or of defence, and the fields would not have been developed to a point at which the home supply could be made full use of. Surely that was a point at which a country might reasonably in some way or other protect its own interests? On the one hand there was the danger that the supplies might be taken out and exhausted too rapidly, and on the other hand there was the danger that in the interests of fields elsewhere, and market considerations generally, they might not be developed as rapidly as they should have been from the local point of view.

Questions of this sort had arisen in the past and might arise again. Therefore, there must be to some extent practical limitations to the application in present circumstances of an extreme doctrine of international altruism, however much one might be disposed to agree with it as a general principle. The paper had given him great delight to read. He thought it was an extremely valuable paper to have in the records of the Institution. It was full of thought and ideas, and would stimulate thought in other persons. Economic and kindred considerations were coming more and more into play every day in connection with many industries. He remembered that when the Fuel Conference was held the previous year, an old friend of his in the Ministry of Munitions, an extremely practical engineer, Sir Philip Nash, had written a letter to the press, in which he summarised different papers that were coming forward, and said that what struck him above all was the way in which economic questions were the links that bound together all those great questions that otherwise might have been treated from too purely technical a standpoint.

From that point of view, too much consideration could not be given to such matters. He had read the paper once carefully, and once again hastily, but he hoped to find time to read it again and ponder over it with the care and attention which the subject and Sir Arnold's able presentation of it so fully deserved.

Major T. R. H. Garrett said there was one point about the paper in which he had been particularly interested, and that was Sir Arnold Wilson's exposition of it. He thought it would be a very desirable feature at the Institution if more authors would follow the same practice. There was, however, one point he desired to criticise, and that was on page 708, the third assumption. He desired to ask the author what he meant by "virtual monopoly." Take, for instance, the outstanding case of nickel. It might be thought that where 94 per cent. was produced by one country that was an absolute monopoly; but it must not be forgotten that although in 1928 Canada produced 44,000 tons of nickel, New

Caledonia 2,400 tons, and the whole of the rest of the world (eight or nine countries) under 800 tons, yet during the war, when she was compelled to do so by stress of circumstances, Germany had managed to raise her production of nickel from within her own borders to over 1,500 tons a year. He did not think, therefore, that the argument that any one country had a monopoly owing to present economic conditions was a very sound one.

Mr. T. Dewhurst said that the impression he had obtained from the paper was that petroleum legislation in Central and South America, and presumably elsewhere, was in a state of flux, and he suspected, and would even suggest, that that condition was partly and even largely due to the fact that scientists and petroleum technologists had had so little to do with the framing of the laws and regulations. The best they as Members of the Institution could do was to stress the fundamental economic importance of the scientific and technological aspects of the matter, and endeavour to show that these were so important that the purely political questions, such as the ownership of mineral rights, the nationality of concessionnaires, etc., were relatively insignificant. In the first place it was, or ought to be, axiomatic that it was to the great advantage of a State that thorough and exhaustive scientific surveys should be carried out to ascertain the whole of the potential mineral wealth of the State, and in that connection one might stress the help that a State could obtain from companies with large, competent and fully-equipped staffs. It was also, of course, of great importance to States that the mineral deposits proved within their territories should be scientifically developed to the fullest extent. In the above directions a State might even go so far as to pass regulations insisting that companies prospecting within its confines should employ competent technologists, and that each and every lessee should be compelled to maintain competent technical services throughout the whole period during which a mineral deposit was being worked. A State should also, solely in its own interests, insist on unit development of each and every individual mineral deposit which, owing to geological structure, was isolated from other deposits. Of all minerals and substances the policy of unit development applied with peculiar force to petroleum, as it was a very easy matter to damage commercial pools of oil. He would also urge that, with sufficient safeguards, a concession for a mineral should be granted to exhaustion of the deposit. Such a course would ensure that sufficient capital would be sunk in the undertaking to obtain the maximum recovery of the mineral. In that connection he referred to a very large country, the mineral development of which had been much handicapped by the

granting of short-term leases. That policy had led to deposits being worked by companies on what he might term the "after me the deluge" lack of principle. The "eyes" of the deposits were picked out prematurely, and the remainder left for subsequent concessionnaires. In that way a great deal of ore was left in the ground which subsequently could not be recovered, and which would have been recovered but for the granting of short-term leases. He felt that Members of the Institution should stress those points, and also other important and relevant scientific and technological aspects of the subject, and thus bring them more strongly into the light, so that when questions of petroleum legislation were under discussion the political difficulties and misunderstandings would be seen in true perspective and would no longer be the dominant factors in the framing of petroleum laws and regulations.

Professor C. V. Illing said that he had travelled in some of the countries concerned and could testify with some feeling to the annoyances and delays due to the uncertainties of the petroleum laws in some parts of South America.

He rather agreed with Sir Frederick Black about the altruism of some of the conceptions which had been put forward. It was not easy to look at a problem from the other man's point of view, but we have to remember that the people of South and Central America were staunch upholders of their own independence and did not view with favour any semblance of foreign interference. It seemed to the speaker that those who wanted to exploit the resources of these countries must give something in exchange; and the most they have to give, more important than the necessary capital, is the work of their technicians. It is probable that many of these countries have large undeveloped petroleum resources. The world had seen in the case of the United States how some of these resources have been gambled away. Personally, he doubted very much whether in some of the older fields more than one barrel of oil had been obtained from the ground for every three barrels that were left underground. This question of efficient extraction is one which every country in the world would be up against sooner or later, for though one might agree that the Americans, some years ago, had over-stressed the limitations of their resources, yet it is vitally true that the petroleum supplies are not unlimited. By drilling deeper we can tap new resources and are doing so, but there is a limit to the process. To the speaker, the subject of ownership is secondary to the problem of development, and it is in this matter that we can give to these countries the benefit of our knowledge.

The production of the largest quantity of oil from the resources underground is of national and international importance. In that particular respect, it seemed to him that the most fruitful work an Institution such as this could do would be in guiding the legislation on petroleum exploitation. Production must be by the best possible methods, with the elimination of water and the conservation of reserves in order to get the maximum extraction. The legal problems should be approached from this point of view, efficiency of recovery.

He felt that a paper like Sir Arnold Wilson's was of immense value in drawing attention to the fact that the problems of ownership and production are interdovetailed and international, and that it behoved the Institution to play its part in conserving these resources.

Sir A. T. Wilson, in reply, thanked the speakers for their very kind reception of his paper, and for a most suggestive discussion. To Sir Frederick Black and to Professor Illing he desired to protest that he was no altruist. He was trying to deal with the problems on a basis which was far from altruistic. He would ask them to remember that not thirty years ago certain South American States had rejoiced in the fact that they had the world monopoly of quinine; within ten years the quinine merchants found they had lost the market. The same had happened in regard to rubber, and to some extent in regard to vegetable tanning materials.

He was inclined to agree with Major Garrett's criticism as to monopolies of raw materials. It was, however, financial rather than territorial control that he had in mind.

He did most wholly sympathise and agree with Mr. Dewhurst as to the importance of the Institution bringing to the fore at all times and in all places, particularly abroad, the scientific outlook and the scientific approach to any problem of legislation on mineral resources. In this country we had the advantage of a Department of Scientific and Industrial Research, but it was only within the last few months that a "scientific group" had been constituted in the House of Commons. In most countries in South America the scientific side of life had scarcely been developed, though nearly all had scientific branches connected with Ministries of Industries. It was the business of the members of that Institution to emphasise, whenever they got the opportunity, the scientific aspect of mineral questions; and he entirely agreed that no question of legislation regarding ownership or taxation could properly be put forward for discussion without technologists, as such, in their technical capacity, having an opportunity of entering into the discussion.

He need only conclude by referring once more to the question of monopolies. He did not intend to suggest, by his altruism, that governments should continue to export oil when it was no longer a commercial proposition. He meant to protest against the idea that oil would stand a sudden heavy taxation for the national benefit because, at the moment, nations were prepared to pay a high price outside. England itself had done that not ten years ago, when a heavy tax was put on coal exported to France, with the worst results to the coal industry; and he fancied that if the same thing was applied to raw petroleum, it was equally likely to damage the industry of the country concerned. Something like that had happened not very long ago in Mexico.

On the motion of the President, a hearty vote of thanks to the author was accorded by acclamation.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

ELEVENTH ANNUAL DINNER.

THE ELEVENTH ANNUAL DINNER OF THE INSTITUTION OF PETROLEUM TECHNOLOGISTS was held at the Connaught Rooms, London, on October 11th, 1929.

The President of the Institution, Dr. A. E. Dunstan, was in the Chair, supported by :—Mr. Alfred C. Adams (Past-President), Major Sir Richard Barnett (Vice-President), Sir Frederick W. Black, K.C.B. (Past-President and Hon. Editor), Prof. Sir John Cadman, G.C.M.G. (Past-President), Mr. Ashley Carter (Member of Council), Mr. C. Dalley (Member of Council), Mr. T. Dewhurst (Member of Council), Mr. Arthur W. Eastlake (Vice-President and Hon. Secretary), Major T. R. H. Garrett (Member of Council), Mr. James Kewley (Member of Council), Prof. A. W. Nash (Member of Council), Mr. J. McConnell Sanders (Member of Council), Mr. George Sell (Assistant Editor), Commander R. E. Stokes-Rees, R.N. (Secretary), Mr. William Sutton (Member of Council) and Mr. A. Beeby Thompson, O.B.E. (Member of Council).

Among the guests present were Sir Brodie H. Henderson, K.C.M.G., C.B. (President, Institution of Civil Engineers), Sir Joseph Petavel, K.B.E. (Director, National Physical Laboratory), Sir Robert Robertson, K.B.E., F.R.S. (Government Chemist), Air Vice-Marshal Sir Vyell Vyvyan, K.C.B., D.S.O., Sir Robert Hadfield, Bt., F.R.S., Mr. H. W. Cole, C.B.E. (Director, Petroleum Department), Major T. H. Crozier (Home Office), Dr. W. Cullen (President, Institution of Mining and Metallurgy), Dr. Frank B. Dehn (Chairman, Chemical Industry Club), Prof. Gregory (President, Geological Society), Mr. W. H. Howe (President, National Lubricating Oil and Grease Federation), Dr. C. H. Lander (H.M. Fuel Research Board), Dr. H. Levinstein (Chairman, Society of Chemical Industry), Mr. T. Outen, Mr. George Patchin (Principal, Sir John Cass Technical Institute), Mr. J. Arthur Reavell (President, Institution of Chemical Engineers) and Prof. Thorpe (President, Chemical Society).

Over 200 members and guests were present.

Announcements and Presentations.

After the Toast of "The King" had been loyally pledged,

The President said: I have three very pleasant duties to perform. The first is to read a telegram which has been received from our branch in Persia. They have telegraphed to us as follows: "On the occasion of the Annual Dinner the Persian Branch send good wishes to the parent Institution." To this we have replied, "The President and Members at the Annual Dinner appreciate greetings from Persian Branch and send all good wishes." I am sure that that meets with the approval of all the members present (Applause).

My second duty is to present the Redwood Medal for the sessions 1927–28 and 1928–29 to Mr. W. H. Fordham, M.A., F.G.S., M.Inst.P.T., for his paper "Geophysical Surveying[1]." This medal was instituted as a permanent memorial to our great founder, Sir Boverton Redwood, Bt. It has been awarded on two previous occasions. The Committee of Award regard this Medal as the highest honour the Institution can confer. I may say that Mr. Fordham was an original member of the Institution in 1913. From 1921 he was field manager in Trinidad, and since 1925 he has specialised in the great science of geophysics. It is my very great pleasure to ask Mr. Fordham to come forward now and receive this honour from the Institution.

Mr. W. H. Fordham, after receiving the Medal, said: I am exceedingly grateful for the honour which the Council has done me in awarding me the Redwood Medal, and on this occasion I would ask your indulgence for a few minutes while I describe the position of British geophysics.

The outstanding events in geophysics during the last nine months were, firstly, a description by Prof. Rankine, published in *Nature* last May, of a seismic survey carried out for the Anglo-Persian Oil Company. The results appear satisfactory, but the investigation was carried out by foreigners. Another important paper, by Hopkins and Wasson, on the Venezuelan oil industry, was published in *The Bulletin of the American Association of Petroleum Geologists*. It is apparent to these authors that geophysics is proving of immense value in the alluvial plains of Venezuela; but here again it would seen that the instruments and personnel employed are largely non-British.

The third important event was the publication by the Cambridge University Press of an excellent book on Applied Physics, by Eve

[1] *J. Inst. Petr. Techn.*, 1929, **15** (72), 35–66.

and Keys, of McGill University. In this case the authors have to thank the Bureau of Mines at Washington for the opportunity to carry out the practical work which they describe.

These instances are sufficient to show that we have been slow to appreciate and develop the new methods. This is the more strange as the subject has many ramifications outside mineral finding, and an enormous amount of successful experimental work on what are essentially geophysical problems has been done in this country. A number of Government Departments have studied special branches of the subject. The War Office was at one time vitally interested in sound range and front line screening; the Admiralty in locating submarines, preventing collisions at sea, and depth finding; and the Air Service in spotting hostile aircraft at night. The Magnetic Survey has been working for years on improvements to survey instruments. The Geological Survey is carrying out experimental gravitational and magnetic investigations. The National Physical Laboratory, when studying flow lines some years ago, evolved an elegant electric method which is perfectly applicable to mineral finding, and it has lately designed an electrical apparatus for measuring with extreme accuracy the vertical component of the earth's magnetic field.

The Science Museum contains an important exhibit of geophysical instruments, with descriptions of surveys and their results, while the Empire Marketing Board is paying half the cost of the Imperial Geophysical Survey in Australia.

The whole of this work appears to have been undertaken by the Departments concerned independently, and without any attempt at co-operation, and my feeling is that if the energy expended had been applied more economically, under the general direction of some central body, this country would have been in a commanding position in the geophysical world, instead of being largely dependent on foreigners for its surveys.

It is in the hope of getting this unsatisfactory state of affairs altered that I have been encouraged to take up so much of your time to-night.

The President: I now have to present the Students' Medal and Prize for the best paper presented by a Student Member during the session. The Institution has many Students in London and Birmingham. It looks upon these students as its future members, and does its best to encourage them. The Medal and Prize are awarded on this occasion to Mr. H. M. Stanley, M.Sc. Prof. Nash, at Birmingham, writes to me that Mr. Stanley was educated at Stratford-on-Avon Grammar School, that he obtained the B.Sc. with first-class honours in Birmingham, and the M.Sc. for his

research in coal tar hydrocarbons. He is now engaged on research in petroleum gas problems.

The Medal and Prize were presented amid applause.

"The Royal Society and Kindred Institutions."

Prof. Sir John Cadman, G.C.M.G., D.Sc., in proposing this toast, said: It is now several years since I attended a dinner of the Institution of Petroleum Technologists, and I presume that it is as a penalty for my absence that this duty, agreeable though it is, has been thrust upon me. It is a toast I am delighted to honour.

First, however, let me say a few words regarding the Institution itself and its worthy President. Although that toast is allotted to a later speaker, it offers such a rich field for comment that the few words I am going to utter will not, I am certain, in any way steal the thunder of the distinguished gentleman who is to propose that toast.

Dr. Dunstan's work is known all over the world, and is esteemed as highly in the United States as in this country—if not, indeed, more highly, for in the United States the great petroleum industry has a wider sphere of activity, and there are far more people actively engaged in its operations. It is a particular pleasure to me to have this opportunity of doing honour to your President, whom I know so well, and for whom I have such an admiration.

This Institution has done remarkable work in a comparatively short space of time. It has brought to bear upon an industry the application of science, to which that industry owes a great debt. It comprises a collection of men who are able to appreciate the various ramifications of science in its incidence upon petroleum and their continual inter-relation; and a body of opinion that has really had—and I speak with some considerable knowledge of the subject—a very important bearing upon industry as a whole.

There is a movement now on foot—it has indeed already been launched—to give the Institution an even greater status in co-operation with some eight other bodies. This movement has for its object the erection of a building, of suitable architecture and dimensions, in which corporate bodies representing the great sciences of mining engineering, of chemical engineering, and of petroleum engineering can be housed in one place. The idea behind this movement is not new; it has been in existence for some years. It would not be unnatural if, say, the officials of some Institutions, already housed in delightful little places of their own, should honestly fear a change of this kind might be injurious, and should

cling to that isolation in which they rejoice. I do not say for one moment that the Secretary of the Institution of Petroleum Technologists or his Council has any such idea, but it is not surprising that when a movement of this kind is started there should be a tendency to feel that it may react unfavourably on the individuality of the body as a whole. But, believe me, the opportunities for collaboration—the common library, the common meeting ground, the common lecture rooms—are going to add prestige and dignity not only to the Institution of Petroleum Technologists, but also to the whole of those units joining together for this special purpose. I am perfectly certain that when the appeal is made handsome support will be extended to this movement by the petroleum industry; and I believe that the other co-operating societies will find a volume of support no less generous from their respective industries.

In the past the application of science to industry has not really had reasonably favourable conditions in which to develop its influence. From many industries the work of the scientist remained far too long detached and inaccessible. Not so, however, in the petroleum industry, where I am confident that in recent years the influence of science has been more marked than in almost any other. That influence is spreading, and now contributes not only to the success of every operation connected with oil-finding, oil-winning and oil-refining, but also to its marketing, transport and distribution.

Certain meetings have taken place within the last eighteen months in an endeavour to find and further some common purpose for the petroleum industry as a whole. Let me emphasise what I have said elsewhere, that no part of the objective of that movement was the establishment of any monopoly or the raising of prices. Its aims were, and are, the introduction and perfection of economic and scientific methods throughout the whole gamut of petroleum affairs. If we want a conspicuous example of the result of a persistent neglect of these aims, we need only turn to some aspects of the coal industry where much of the prevailing chaos is due to failure to grasp the fact that the industry as a whole is far more extensive than the mere locality within which a few coal mines exist. If a tremendous economic fact like this is to be brought home to the minds of those responsible for any industry, then concerted speech and action on the part of the scientists engaged in the development work of other industries can best do so. It is that very form of co-ordinated effort which the various institutes and societies now planning to get a central building can admirably afford, given a unified domicile. By the mere contact one with another, by their interchange of ideas, and by the example set by the more progressive among them,

a result will be reached far exceeding that which they could individually attain.

My toast is "The Royal Society and Kindred Institutions." I should like to refer for one moment to the influence of the Royal Society in admitting and maintaining a distinction which I hope in future it will do everything possible to cancel. Some of our scientists—among them, for all I know, members of the Royal Society—have in their widsom thought it right to attempt to divide the realm of science into two hemispheres, that of "pure" and of "applied" science. I do not suggest that this distinction is without some theoretical or metaphysical basis, but I am certain that, in effect, it has injured, or at least retarded, that steady advance in the value of science's contribution to industry. After all, the so-called "pure" science of yesterday is indistinguishable from the enlightened practice of to-day, and personally I would appeal to the Royal Society and its kindred institutions to recognise the unity of thought linking up the remote speculation of the scientist's brain with what may prove its inevitable application in the chemist's laboratory or the engineer's workshop. It is a commonplace of industrialism to-day for its leaders to seek the counsel of professors of "pure" science, and I suggest we should do everything to foster the closest intimacy and the completest contact between the two. Because of the imperfection of that contact in the past, we in this country stand in some danger of lagging far behind other countries—Continental as well as American. Every readjustment that facilitates the desired perfection of co-operation—and, incidentally, the movements of which I spoke a moment ago for housing many societies under one roof is an excellent example—fully deserves, and I am sure has a right to look for, the hearty support of the Royal Society and of kindred institutions. I hope and believe such movements will not be in vain.

Gentlemen, you will gather from what I have said that I think the influence, and the potential influence, on our everyday life of the work of the Royal Society and of kindred institutions can scarcely be exaggerated. My own complaint, or suggestion of complaint, is that they or some of their members sometimes may be inclined to under-rate the immediacy and importance of the practical application of that work. There is no need for me to enlarge upon the unparalleled eminence of the Royal Society itself or upon the unique equipment which its members bring to the ever-increasing problems of our very complicated industrial civilisation.

Gentlemen, it is my privilege to couple with this toast the name of a very distinguished scientist, Sir Robert Robertson. He is one of that invaluable body of silent workers who are well content to

render the fruits of their labours to the particular Government department to which they are attached, knowing that, in the long run, the whole nation and, indeed, the whole world may reap the benefit. In that knowledge, Sir Robert Robertson and those like him, care little about the absence of those individual forms of recognition which quite properly are heaped upon workers, no more distinguished than he, in other fields. It is, therefore, all the more gratifying to me to be able on this occasion to associate his name with the toast which I now ask you to drink—that of "The Royal Society and Kindred Institutions."

Sir Robert Robertson, K.B.E., F.R.S.: Mr. President, It may seem ungracious after the nice things that Sir John Cadman has said about me to join issue with him at once. But I am going to do so. He accuses the Royal Society of being the originator of that divorce in people's minds between pure and applied science. Surely that is not the case. The Royal Society was founded for the extension of knowledge, but, apart from that, if Sir John will take up the May number of the *Proceedings of the Royal Society* he will see there a paper by Prof. Wilson of Texas on the cracking of petroleum. It is true that the subject is discussed in the first place from the purely mathematical point of view, but towards the end of the paper he talks in terms of "barrels of oil," and what could be more applied than that?

But this distinction between pure and applied science really no longer holds the field. We know that there is only one science followed by those who have a desire for knowledge and for truth, and there are the various applications of that science.

Sir John has told us of the debt that industry owes to science. But we might equally make a point of the debt which science owes to industry. Take this wonderful product of yours, petroleum, and consider what enormous advantages it has given to scientific workers. We have, in the first place, the material itself, which is so fascinating, and then we have all the problems that are connected with it. Let me take one or two examples to elaborate that point. Consider the phenomena of combustion. The initial stages of combustion have been recently explored, and much scientific light has been thrown upon them by the fact that a certain ingredient was added to prevent "knocking." This investigation has led, not only to an elaboration of theories of "knocking" but also to a much better appreciation of what underlies combustion in its early stages.

Then take the question of cracking. I have already spoken of the important paper from the physico-chemical point of view of Prof. Wilson. Those of us who attended the last Soirée of the Royal Society had the opportunity of seeing the apparatus of your

President in which cracking was carried on before our eyes; we saw through glass the vapours at the critical point—a beautiful piece of apparatus, not only from the point of view of general scientific interest, but also as exemplifying a process which the President wanted to demonstrate. The results of this cracking are manifold, and may have enormous influence on our civilization. No one can prognosticate what will be produced as the result of cracking. Indeed, it may be claimed that the aliphatic chemistry of the future will run along the lines of the cracking of petroleum bodies, and a greater chemistry may arise—it will be a most difficult one, because the substances are less tractable than those of the aromatic series—the applied results of which no one can foresee. But already we are beginning to have some glimpses into this matter. Take the gaseous products of cracking. From ethylene we get glycol, alcohol and acetic acid, and from glycol we obtain ethers now used so widely as solvents. These are bodies which, only one or two years ago, were chemical curiosities, and now they are being made by the ton. A whole range of alcohols is being made. We may, indeed, even get glycerine in such a way, and from its combination with synthetic fatty acids, edible fats which may be the saving of the human race from starvation. At present medicinal paraffin is used, but nobody claims any nourishment from paraffin. When, however, we are able to produce an edible substance, no one can say what it may lead to. The only thing wanting appears to be the vitamins. (Laughter and Applause.)

Then it may be claimed, from the point of view of pure chemistry, that these petroleum products have given chemists a body of material of the greatest importance. Gaps are being filled up in the scheme of organic chemistry, and new bodies are being prepared, and their chemical and physical properties discussed in the light of their structure. These are some of the advantages, but there are many others of very great interest to the chemist, and the investigation of these oils requires organic chemists of the highest competence.

Again, we have heard to-night something about your geophysical work. That touches on the domain of physics. I have no doubt at all that the problems of the geologist in the oilfields are going to react upon physics and geophysics in a manner which all geophysicists will welcome. This is another example of the reciprocal movement which Sir John has mentioned, and it illustrates the indebtedness of science to industry.

The future, as I have said, is bound to lead to enormous advances in the treatment of your product. In fact, one may conceive, that instead of the term "petroleum technologists" you may some day wish to call yourselves "chemical engineers." (Applause.)

"The Institution of Petroleum Technologists."

Sir Joseph Petavel, K.B.E., in proposing the Toast of the Institution, said:

I understand, gentlemen, that your Institution is not only world-wide in its action, but cosmopolitan in its membership, and comprehensive of the whole of the science and technology of this subject. If, therefore, Sir John Cadman had not anticipated me, my speech, having to treat of all these matters, would have been lengthy. You have an unlimited development in the three directions I have just mentioned. Geographical difficulties might in earlier days have rendered it a little difficult to run sections in Rumania, and in Trinidad, and in Persia. But, thanks to the results of science, you can now—or you will be able to in a very short time—hold joint meetings with these sections over the wireless telephone. Your cosmopoltian character might have led to the same difficulties of discussion which international congresses occasionally experience. But I think the vitality of the main element in the Society and the vigour of the English language will offer complete facility for the Persian to talk to the Czecho-Slovakian. (Laughter.) There remains, however, one difficulty, namely, that science, which you subdivide into geology, engineering, physics, chemistry, mining, and so on, and which, of course, are all parts of the preoccupations and discussions of the petroleum technologists, is so subdivided into such a multitude of sections, that each section speaks a language or a dialect incomprehensible to any of its neighbours. It is, there-, fore, one of the main problems which your Institution has to study how it can become a parliament, a house of exchange of scientific knowledge, and not merely a tower of Babel, where no two men understand the words or the objects of any other two.

With regard to your main preoccupation, that of petroleum, there is no doubt that this is the magician of our present civilisation. Further, there is the strange phenomenon that the industries of both war and peace subsist on the same nourishment. I understand that in the past distinguished and eloquent members of the Services have paid tribute to the work done by your Institution in forwarding their aims, and that in the future able members of the various peaceful industries will rise to congratulate you on the help you have given them. The question is, what remains for a poor person like myself to say? I propose, merely, gentlemen, to say a few words about scientific research and the advancement of knowledge. Your Institution is remarkable in that, in the field, your members are using instruments the delicacy of which would have frightened the researcher if they had a few years ago been proposed for ordinary use in the physical laboratory. These instruments depend and

work on the law of gravity, or the resistance of materials, or the magnetic properties of the material, or the velocity of sound in the crust of the earth; and in all those cases the results necessitate the highest mathematical analyses which not long ago would have been thought to be merely a philosophical study. Some of your members are concerned with the effective exploitation of oilfields, and they have to call on the latest advances of civil and mechanical engineering, on mining, and even on naval architecture. At home, Sir Robert has already indicated the large scope the petroleum development has offered to the modern chemist, and I need hardly refer—it would be commonplace—to the extent to which the mechanical engineer and his devices depend upon your work. Such men as your distinguished President, whose career I was about to refer to had not Sir John Cadman already given a well-chosen summary, are ever widening the scope of the usefulness of petroleum, in the same way as your pioneers are endeavouring to increase the available supply.

I may add that so far as we can at the National Physical Laboratory we have tried to be of use to you—("Hear, hear.")—and in many discussions on standardization mostly, we have been able to render some assistance. I hope that that co-operation will be extended and increased, and that many of these investigations will be undertaken jointly with your Institution. I saw with surprise the rapid growth and progress which your Institution has made during its relatively short career. I should not like to apply ordinary mathematics to this question, but when you have reached the age of the Royal Society it is quite clear that at this rate no living human being of ability and scientific knowledge will be outside the scope of the Institution of Petroleum Technologists! But, gentlemen, that growth is justified, and an increased growth will be secured, in the measure in which you are able to support, and persuade others to support, research and the increase of knowledge. I ask you to drink to the Institution, coupled with the name of your distinguished President.

The Toast was drunk with acclamation.

The President (Dr. A. E. Dunstan), who was received with loud applause, in responding to the toast said: Gentlemen, When it fell to my lot to have the task of addressing you to-night as President, I took the opportunity of carefully studying the speeches of my distinguished predecessors and found, broadly, that these eminent men all emphasised the importance and the value of the Institution of Petroleum Technologists both as a centre for research and investigation and as a general guide to the petroleum industry. Nothing has hitherto been said about the members themselves.

I, therefore, propose with your forbearance to discuss to-night the Institution as seen from the standpoint of the ordinary member who yearly pays his subscription, usually, I imagine, like every other taxpayer, with some grumbling. He asks the question—what do I get out of it all? I propose to tell him and those of you gentlemen who fall in this category.

We Britishers are at once the most "clubbable" and the most centrifugal of peoples. Whenever two or more of us get together we form a club, a society or an institute—and not infrequently we split up these original bodies into a series of smaller groupings.

We find, for example, that our parent Chemical Society with nearly a century of effort giving rise to daughter institutions dealing with chemical industry, chemical engineering, rubber, oil and fats, electro-chemistry and so on. Indeed, our world-famous Royal Society may truly be regarded as the parent of the hundreds of scientific and technical associations existing in the country to-day.

Now, clearly, there is something to be said for being a member of a corporate body. Did not Plato say 2,000 years ago "The aim of a veritable community is not that this or that individual should prosper but that the whole shall flourish." For wisdom one should always consult the ancient Greeks.

In such a community as ours do we attend to this saying? I think we do and I desire now to indicate in what ways we do attempt to justify our members' continued support.

In the very forefront of our value to our members, I put the Journal—possibly because I see it as a much-loved endeavour of my own with a nine-years' immediate and personal responsibility to Council for its continued success.

Recently in the U.S.A. I heard many kind things said about our Journal and repeatedly overseas members speak of its value to them, divorced as they are from current literature.

By means of its Journal, the Institution is able to do good service, not only to its members, but to the petroleum industry as a whole. It is fitting that reference should be made here to our first editor, Mr. W. H. Dalton, F.G.S., whose lamented decease has just been announced. He took over the Journal at the very start and officiated till December, 1920. Not only was he an eminent geologist but a writer of outstanding merit. Writing in No. 1 of the Journal he said :—

> "It will be the aim of those responsible for the conduct of the proceedings of the Institution to keep in view, not only the application of science to the various branches of the industry, but also the results of research work in pure science in relation to questions which may prove to have far-reaching industrial effects."

How far these precepts have been attained can best be judged by a perusal of the Journal itself, and I feel confident that such perusal

will not lead to disappointment. So far we have published nearly fifteen volumes, seventy-five separate numbers, numbering 10,425 pages, of the Journal, and each volume has contained papers and articles of interest to all branches of the industry, geological, engineering, chemical and administrative.

During the last eight years, each number of the Journal has contained a series of abstracts of current literature and of patent specifications. Over 5,000 such abstracts have appeared, and the usefulness of these to those actively engaged in the industry cannot be over-estimated. (Applause.)

For several years it has also been our custom to publish a series of reports on the progress of naphthology, and in these the current developments in each particular sphere have been brought together and correlated to form a useful guide to up-to-date practice.

In the past few years the Journal has been published in six parts per annum, but commencing with next year it is proposed to increase this number to nine. By this means it will be possible to expedite the publication of important matter and to keep the abstracts as up to date as possible.

Originally we published 250 copies per issue. Now we put out 1,750 and very shortly shall increase this to 2,000. So fast are the earlier numbers being sold out that we have had in a number of cases to reproduce our issues.

I would next draw your attention to a more recent development not yet crystallised and still somewhat amorphous. I refer to the development of our library into an information bureau. Books and journals as such are useless things. What you can get out of them is what really matters and we have felt that the usefulness of our library could be immensely increased if we had some organisation for digging out information, classifying it and distributing it to our members. This is in being and the steadily increasing call on this particular service is ample proof that it is of value.

The library is consulted daily, either by personal visits, correspondence or by telephone. The number of enquiries received from members and other individuals, and Government and other important concerns, not only in this country but abroad, shows a steady increase. The total number of such enquiries for the past year amounts to over 1,000.

It is our desire to increase the facilities of the information bureau and make it useful more particularly to members abroad, and any suggestions that would help to further this object will be gratefully received for consideration.

Whilst our general scientific meetings remain as popular as ever judging by the uniformly excellent attendance, it is clear that they only provide for a tithe of our world-scattered membership.

Council has given every encouragement and assistance towards the formation of branches so that, wherever two or three petroleum technologists are gathered together, there shall the Institution of Petroleum Technologists be present. The existing branches last year in Rumania, Trinidad and Persia are all flourishing. Just recently the South Wales Branch was established with headquarters at Llandarcy. According to their last reports these branches number 162 members, who by meetings and discussions keep alive that spirit of good fellowship that is so characteristic of our Institution.

Council has given every support to the suggestion that a benevolent fund should be established, and I wish to take advantage of this Dinner to press its claims. The great majority of professional institutions has found it necessary, sooner or later, to come to the assistance of disabled members and their dependants and we are, I am sure, doing a wise thing in getting our fund under way before we are seriously pressed for help.

I would urge every member to add to his annual subscription some amount that he can afford. More is done by the annual integration of small amounts in large numbers than by the generous response of the few. We want both. The Institution is doing so much for its students and its members that a voluntary goodwill offering to this deserving cause calls for no words of mine but only your response. (Applause.)

It will be known to all here that active steps are being taken to provide adequate housing facilities for a number of institutions and that this scheme has been immensely furthered by the adherents of the powerful chemical group. The scheme provides for common lecture halls and a general library—the club facilities and amenities that the individual societies do not and cannot at present possess.

I should refer here to the work of the Standardization Committee. This Committee published its first report on the " Standard Methods of Testing Petroleum and Its Products " in 1924. Since that time the Committee has continued its activities and this year has published a revised edition of its testing methods. The support given by the industry, and by outside bodies, in the demand for copies of the book leaves no doubt as to the value of this work, and the thanks of all are due to the members of the Committee for the valuable experience and time which they have freely given to its deliberations. And acknowledgment should be made here to the willing assistance given by many Government Departments—The National Physical Laboratory, the Government chemist and the staffs of the various oil companies.

I envisage the closer and closer co-operation of our American friends in this matter. So far as is possible the Standard Methods

of the A.S.T.M. have been incorporated with our own procedure and I, for one, look forward with confidence to the time when there will be one and only one book of Standard Tests—international in scope and English in language. The compliment paid to the Institution by my appointment as honorary chairman of the A.S.T.M. Committee on methods of tests for petroleum products and lubricating oils, has been highly appreciated on this side of the Atlantic.

The Membership on the date of the last dinner was 1066 and at the present time it has increased to 1,169 and there are 31 candidates awaiting election. We progress in a linear relationship.

During the year October, 1928—October 1929, the Institution has been represented at the following Congresses :—

The Worlds' Power Conference, Fuel Conference, London, 1928, by The President, Mr. Kewley, Mr. Young and Dr. Dunstan.

Second International Conference on Bituminous Coal, Pittsburgh, November 19–24th, 1928, by Dr. Dunstan and Dr. Lessing.

Second International Drilling Congress, Paris, September 16th–22nd, 1929, by Mr. Ashley Carter.

The British Drilling Committee was formed at the request of His Majesty's Government, and the work in connection with it undertaken by the Institution.

The Institution has also sent papers and a Complimentary Address to the World Engineering Congress which is taking place in Tokyo in October this month, also papers have been submitted for and representatives will be attending the Ninth Congress de Chimie Industrielle which is being held in Barcelona during the month and further it is to be represented at the Empire Mining and Metallurgical Congress in South Africa.

The Social side of the Institution is not neglected and we have arranged a joint evening with the Oil Industries Club on December 5th next, and a Conversazione at the Royal Society of Arts, on Thursday, December 19th.

It would be impossible to survey the progress of the Institution during the past year without referring to the outstanding work of our past-Presidents. As I pointed out in the inaugural address last March, I know of no body that possesses such a group of hard workers as our own past presidents. To Sir Frederick Black, I, personally, am indebted because with great enthusiasm he took over the honorary editorship of the Journal when I was elected president. His work on Council, the Standardization Committee, and, indeed, most of our Committees is of outstanding merit. (Applause.)

Again, Professor Brame undertook the arduous duty of producing the second edition of our Standard Tests, and to him our thanks are due; whilst Mr. Adams still sits as our Chancellor of the Exchequer with very obvious benefit to the Institution. (Applause.)

Mr. George Sell, who has been my *Fidus Achates* for many years, has again served the Journal and the Standardization Committee with conspicuous success. (Applause.) Our abstracts, to my mind one of the outstanding features of the Journal, are carried out by Mr. W. H. Thomas in the most able manner.

To Mr. Ashley Carter the popular secretary of the dinner Committee, our best thanks are due for his unfailing courtesy and his strenuous work for so many years in connection with our annual banquet.

I can find nothing new to say about our Secretary and his staff. I merely quote the tag—"*Si monumentum requiris, circumspice.*"

"Our Guests."

Major Sir Richard Barnett (Vice-President), in proposing this toast, said: There are two ways of proposing the health of "The Guests." One is the rather banal way of quoting long extracts from "Who's Who" and other works of reference. The other is the method invented by my friend the late Mr. Mostyn Pigott, who achieved a great reputation as an after-dinner speaker by naming all the visitors in turn and telling stories, often amusing, generally libellous, and, of course, invariably apocryphal, about their life and conversation. I hope that our distinguished guests this evening will keep their seats; there is no danger. (Laughter.) I know nothing to their detriment; I could not say it if I would, and I would not if I could.

Glancing through the list of those who have honoured us with their presence to-night, I am much impressed by the number who have rendered good service to our country and gained distinction, or added distinction, in the Great War. If we can believe the newspapers—not always an easy task nowadays—it really looks as though the nations are making up their minds to learn war no more. But I hope that the eminent chemists, engineers, and steel manufacturers who are here this evening will take heart of grace. There will be plenty for them to do, even if war becomes a thing of the past. Take steel to begin with, and Sheffield is very adequately represented by Sir Robert Hadfield—(Applause)—the veteran inventor of manganese steel and silicon steel. Well, if we do not want steel in future for building warships, we shall want it for ocean liners and for oil tanks and oil tankers. If we

do not beat our swords and bayonets into ploughshares, at any rate we can convert them into drilling machinery. As for our chemists, we may not ask them to find a gas to poison the King's enemies, but we shall still require their services to analyse the gas of the mine and that of the casing head. We have here this evening in Sir Robert Robertson one of the leading authorities on explosives, and we have also, I believe, H.M. Chief Inspector of Explosives. If we do not ask them in the future for means to blow our fellow men to pieces, there are thousands of obstacles in the road of progress to be removed, and in our own calling we shall find a use for a certain amount of high explosive when searching for hidden structure by means of the seismograph. Peace hath her victories no less renowned than war, and her dangers and adventures also. Anyone in this City of London who goes evening after evening to his home in the suburbs has to meet dangers not dissimilar from those of the trenches. It has been well said that although the horizontal lines which divide society into different classes are fast disappearing, in our great cities there is a vertical line which divides the whole population into two great categories, namely, the quick and the dead. (Laughter.) I am afraid that our petroleum industry has done something to sharpen this sinister classification.

We have very distinguished representatives of learned bodies, like the Royal Society, whose President we had hoped to see. Sir Robert Robertson has, however, ably defended that ancient institution from the onslaught made upon it by Sir John Cadman. As a loyal son of Wadham, the college within whose walls the Royal Society was born, I must say that I sympathise with Sir Robert. We have the greatest respect for the Royal Society. We are all inclined to regard it as being a little "highbrow," but critics say that even about our own Institution here. (Laughter and applause.) I have heard people say it after listening to our papers and discussions.

A number of gentlemen whom we had hoped to see to-night have sent letters of regret. Among them are Viscount Bearsted, Viscount Cowdray, Mr. Andrew Agnew, Mr. F. E. Powell, and Professor Henry Louis. We have also had a telegram from Herr Alfred Wirth, sent off this evening from Berlin, expressing his best wishes for a successful evening. To all those guests who have been able to come we, of the Institution of Petroleum Technologists, extend our warmest welcome. We are delighted to see them, and the oftener that they can come to our Annual Dinners the better we shall be pleased. I ask you all to be upstanding and drink the health of Our Guests.

Sir Brodie H. Henderson, K.C.M.G., C.B. (President of the Institution of Civil Engineers), in responding on behalf of the Guests, said: We received and accepted your kind invitation to this Dinner to-night with the full anticipation of passing an enjoyable and instructive evening, and our hopes have not been disappointed. I can assure you, Sir and Gentlemen, that we have had a most enjoyable evening, and we have listened to your speech with the greatest possible interest. Speaking as President of the oldest engineering institution in the world, I find it almost impossible to understand how you have been able to achieve so much in a comparatively short time. It is really wonderful, and we all congratulate you most heartily on the success of your efforts. I was particularly interested in Sir John Cadman's remarks about a Central House. We older Institutions some years ago endeavoured to carry out some such idea. Instead of having various institutions housed under different roofs, we endeavoured to form one centre in one building, but we encountered difficulties which it was impossible to overcome, and we failed to achieve our object. I hope that you will be more successful than we were, and I am quite sure it will be a good thing for all concerned.

I, fortunately, from one point of view, come at the end of your Toast List when long speeches are ruled out. Therefore I am not going to occupy your time for many moments. I remember, when I was a young man, coming across some question in connection with petroleum, and going to consult with the then greatest expert on the subject, a man whose name has been mentioned here to-night. After having discussed the particular business about which I went to see him, we began to talk in a general way about the petroleum supplies of the world, and he gave it to me as his considered opinion that possibly he, but certainly I, who was a much younger man, would live to see the end of the supplies of petroleum in the world. Well, gentlemen, I am glad to say that he was wrong. I have just come from a longish journey, having been absent from this country for some months, and I have visited a country which is developing in your line and which, from all I have heard from those who ought to know, is full of possibilities for the extraction of petroleum. I believe that, a hundred years hence, the supplies contained in that country will just be beginning to be attacked. Therefore I presume that the petroleum industry is really only in its infancy. With the great resources of science of which we have heard so much to-night, you must have before you a glorious career.

I wish your Institution and every member of it the greatest possible success in the future. I hear whispers—whether well-founded or not I do not know—that there is some idea that you

should apply to the Privy Council for a Royal Charter, which seems to be the fashion nowadays. If it is your desire to obtain a Royal Charter I hope you will be successful. On behalf of all your Guests, I express again our most grateful thanks to you for a most enjoyable evening.

The proceedings closed with the singing of the National Anthem and "Auld Lang Syne."

9eme Congres de Chimie Industrielle, Barcelona, October 14th to 19th, 1929.

AT the request of the Council of the Institution of Petroleum Technologists, the undersigned attended the above Congress as delegate of the Institution.

A certain number of papers of interest to Petroleum Technologists were on the programme, but with one or two exceptions the authors did not present their communications in person, nor were they read. The notes hereafter are, therefore, translations from the précis of the papers published in the proceedings of the Société de Chimie Industrielle :—

The Sulphocyanide Value as a Method of Determining Unsaturated Hydrocarbons. By Messrs. H. Hugel and Krassilchik.

A great deal of work has been carried out on methods of determination of unsaturated hydrocarbons, principally by means of the addition of iodine or bromine to the double bonds. Pure iodine combines very slowly whereas bromine being too active gives substitution as well as addition products. Rhodane, discovered by Soederback, has been used by Kaufmann for the determination of unsaturation in vegetable oils.

To the best of our knowledge this method has not been applied to unsaturated hydrocarbons.

The authors have discovered that sulphocyanide dissolved in glacial acetic acid gives only addition products ; hydrocarbons which easily form substitution products with bromine, *e.g.*, terpenes and aromatic hydrocarbons, show no traces of substitution reactions even with concentrated solutions of rhodane.

Di-olefins such as isoprene which give with bromine results difficult to interpret take into combination one molecule of sulphocyanide in the position 1, 4 and the reaction then ceases.

The mechanism of the addition of sulphocyanide to the double bond has been studied. The reaction velocity curve follows the law of bi-molecular reactions and the velocity constants are the same for all the members of any given series of hydrocarbons, for example, the -olefins. This has been checked with -heptene, -octene, -duo-decene, -tetra-decene and -hexa-decene.

There are other velocity constants depending upon the position of the double bond in the chain (*e.g.*, B-octene) or in a ring (*e.g.*, cyclo-hexene).

The regularity of the addition of sulphocyanide to the double bond is specially notable in view of the fact that it has not been possible till now to discover a similar reaction in the case of bromine.

The Reactions Produced in Pure Unsaturated Hydrocarbons by Heat under High Pressures. By Messrs. G. Hugel and Cohn.

The object of this work was to contribute to the study of the cracking of hydrocarbons and determining the influence of physical factors.

It is, however, very difficult to study the cracking of hydrocarbon as a function of a single physical factor because the variables are not independent. Among the various physical factors which influence cracking we have been able to discover in addition to the temperature, the pressure and the time of the reaction, certain new factors such as, for example, the presence of a vapour phase (consisting of the vapour of the hydrocarbon in question or a foreign gas) and also the ratio of the liquid to vapour phases.

The object of the authors being to study the influence of the temperature and pressure only, they excluded the other factors mentioned above by working, in the absence of all vapour phase, by means of high pressures and by carefully excluding any foreign gas.

At the beginning of the work temperatures of 300° and pressures varying between 5 and 1000 atm. were used. Under these conditions the only reaction which it was possible to discover was that of polymerisation of hexa-decene to $C_{32}H_{64}$ and $C_{48}H_{96}$. The reaction of the polymerisation of hexa-decene was studied as a function of pressure and of time. It was the more accentuated as the pressure rose, particularly above 500 atm. The study of this reaction as a function of time shows that it is probably an equilibrium reaction. The equilibrium appears to depend on the pressure and the temperature.

Production of Benzene and the Polymers of Acetylene by Pyrogenic Condensation. By Mr. J. Ylla-Conte.

Acetylene is subject to pyrogenic condensation at a temperature of 450/600°. The reaction is carried out in large chambers of sheet iron and owing to their capacity the surface of metal in contact with the acetylene can be considered as nil.

The acetylene is kept in movement so that the temperature of reaction remains constant.

The heat is absorbed by a refrigerant. The circulation of the acetylene through the refrigerant throws down by condensation the benzene and liquid hydrocarbons formed.

Once the operation has been started it is not necessary to heat the acetylene and the operation is continuous and automatic. By regulating the speed of circulation through the refrigerant one can obtain at will a large quantity of benzene and a small quantity of heavy oil or the opposite.

The Action of Ultra-Violet Light on Benzol. By Mr. A. Mailhe.

The benzol formed by the carbonisation of coal is nearly all carried off by the gases of distillation from which it is recovered by scrubbing with heavy oil or adsorption by means of activated charcoal. The benzol has a yellow colour which deepens with time. In addition to the aromatic hydrocarbons it contains unsaturated hydrocarbons, both olefins and di-olefins. The di-olefins tend to polymerise and produce resinous substances. There are two sorts of di-olefins: the first, which are the true di-olefins and which resinify easily, and the other potential di-olefins which only polymerise after a fairly long time or under certain physical and chemical conditions.

Ultra-violet light produces this reaction and the white benzol becomes very yellow. Nevertheless, we have noticed that in old benzols, from which the unsaturated components have been completely removed by sulphuric acid, still become yellow under the action of ultra-violet light.

It appears, therefore, that the colour which grows in benzol is not entirely due to polymerisation of di-olefins.

To clear up this question we have carried out a series of tests using ultra-violet light on pure synthetic benzol to which we added small quantities of products identical or similar to those normally found in gas works benzol. From the results obtained it appears that the use of ultra-violet light for the determination of resinification in commercial benzols gives figures which are much too high in dry residues and that this method cannot be used for the exact determination of polymerisable di-olefins.

On a Criterion for the Purification of Motor Benzol. By Messrs. R. Brunschwig and L. Jacqué.

The increasing demand for motor benzol has led to a large number of improvements in its manufacture and in the methods of treatment often very different from those used for chemically-prepared benzol. For instance,

9eme Congres de Chimie Industrielle, Barcelona, October 14th to 19th, 1929.

AT the request of the Council of the Institution of Petroleum Technologists, the undersigned attended the above Congress as delegate of the Institution.

A certain number of papers of interest to Petroleum Technologists were on the programme, but with one or two exceptions the authors did not present their communications in person, nor were they read. The notes hereafter are, therefore, translations from the précis of the papers published in the proceedings of the Société de Chimie Industrielle :—

The Sulphocyanide Value as a Method of Determining Unsaturated Hydrocarbons. By Messrs. H. Hugel and Krassilchik.

A great deal of work has been carried out on methods of determination of unsaturated hydrocarbons, principally by means of the addition of iodine or bromine to the double bonds. Pure iodine combines very slowly whereas bromine being too active gives substitution as well as addition products. Rhodane, discovered by Soederback, has been used by Kaufmann for the determination of unsaturation in vegetable oils.

To the best of our knowledge this method has not been applied to unsaturated hydrocarbons.

The authors have discovered that sulphocyanide dissolved in glacial acetic acid gives only addition products ; hydrocarbons which easily form substitution products with bromine, *e.g.*, terpenes and aromatic hydrocarbons, show no traces of substitution reactions even with concentrated solutions of rhodane.

Di-olefins such as isoprene which give with bromine results difficult to interpret take into combination one molecule of sulphocyanide in the position 1, 4 and the reaction then ceases.

The mechanism of the addition of sulphocyanide to the double bond has been studied. The reaction velocity curve follows the law of bi-molecular reactions and the velocity constants are the same for all the members of any given series of hydrocarbons, for example, the -olefins. This has been checked with -heptene, -octene, -duo-decene, -tetra-decene and -hexa-decene.

There are other velocity constants depending upon the position of the double bond in the chain (*e.g.*, B-octene) or in a ring (*e.g.*, cyclo-hexene).

The regularity of the addition of sulphocyanide to the double bond is specially notable in view of the fact that it has not been possible till now to discover a similar reaction in the case of bromine.

The Reactions Produced in Pure Unsaturated Hydrocarbons by Heat under High Pressures. By Messrs. G. Hugel and Cohn.

The object of this work was to contribute to the study of the cracking of hydrocarbons and determining the influence of physical factors.

It is, however, very difficult to study the cracking of hydrocarbon as a function of a single physical factor because the variables are not independent. Among the various physical factors which influence cracking we have been able to discover in addition to the temperature, the pressure and the time of the reaction, certain new factors such as, for example, the presence of a vapour phase (consisting of the vapour of the hydrocarbon in question or a foreign gas) and also the ratio of the liquid to vapour phases.

The object of the authors being to study the influence of the temperature and pressure only, they excluded the other factors mentioned above by working, in the absence of all vapour phase, by means of high pressures and by carefully excluding any foreign gas.

At the beginning of the work temperatures of 300° and pressures varying between 5 and 1000 atm. were used. Under these conditions the only reaction which it was possible to discover was that of polymerisation of hexa-decene to $C_{32}H_{64}$ and $C_{48}H_{48}$. The reaction of the polymerisation of hexa-decene was studied as a function of pressure and of time. It was the more accentuated as the pressure rose, particularly above 500 atm. The study of this reaction as a function of time shows that it is probably an equilibrium reaction. The equilibrium appears to depend on the pressure and the temperature.

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producers such as the National Benzol Association, the Benzol-Verband and the Union Française des Producteurs de Benzole, have been led to study the criterions necessary to guide the producers as to the quality of their motor benzol. The research carried out by the French group is under the direction of Mr. Mailhe, Professor at the Faculté de Science de Paris.

The authors, referring to a previous paper by Mr. Brunschwig, dealing with the problem of the production and use of benzols, have examined a point which has proved difficult to all chemists who have studied the question of purification of motor benzol, to wit, the question of gums and resins.

It was natural to check the sufficient elimination of gums and resins by a colorimetric test after concentrated sulphuric acid when the purification of the benzol was exclusively carried out by a treatment with this acid. This method of treatment entails the loss of a large quantity (up to 15 or 20 per cent.) of the valuable constituents of motor benzol; all the olefins and even some sulphonated aromatic fractions. Now that the attempt is being made to introduce methods of treatment which conserve these valuable constituents there is no longer reason to use the sulphuric acid test since it gives a coloured reaction with constituents which are useful in engines.

The residue left after a simple evaporation of a sample of motor benzol tells one its actual content in resins, but as this content can increase with storage it is necessary for the estimation of the perfection of the treatment to obtain a figure for the tendency of the benzol to resinify.

A controlled oxidisation obtained by bubbling air through the hot benzol followed by evaporation appears to transform the potential resins into actual ones under conditions similar to those obtained by natural ageing and this has been confirmed by comparative tests.

A simple standard apparatus has been made for the application of this method and is at present being tried out by a certain number of French producers.

A certain number of other papers were on the Agenda. of which, however, no précis have been published.

A complete report on the Congress, including the full texts of all the papers, will be published some time in the spring of 1930.

M. E. HUBBARD.

Paris, October 26th, 1929.

INSTITUTION OF PETROLEUM TECHNOLOGISTS.

World Engineering Congress, Tokyo, 1929.

The President, Past-Presidents, Vice-Presidents, Council and Members of the Institution of Petroleum Technologists appreciate most highly the honour of associating themselves with other learned and technical bodies in the World Engineering Congress, which is being held in Tokyo.

They realise that the scope of applied science is world-wide, and that it is most fitting that a Congress of the magnitude of the World Engineering Congress should take place in your great country, a country that has been characterised by such assiduity and rigour in Technical Development.

The Institution of Petroleum Technologists is very particularly concerned with the most scientific methods of the finding and utilisation of Petroleum and its products, and therefore a series of papers have been presented by Members which, it is hoped, will be of interest to the Congress.

It is in honour of your great country that the Institution of Petroleum Technologists, representative of workers in Oilfields and other branches of the industry throughout the world, respectfully tender this Address on the occasion of the World Engineering Congress.

A. E. Dunstan, *President.*
Arthur W. Eastlake, *Vice-President and Honorary Secretary.*
Rowland E. Stokes-Rees, *Secretary.*

The Officers and Members of the World Engineering Congress, now assembled in Tokyo, wish to acknowledge the receipt of the most cordial Greeting of the Institution of Petroleum Technologists, sent on the occasion of the opening of the Congress.

The Greeting was presented to the Congress at the opening ceremony held at the Tokyo Municipal Auditorium on Tuesday, October 29, 1929, and added to the dignity and brilliancy of the occasion in a very large measure.

Deeply appreciating the great honour so conferred upon them, the Officers and Members of the Congress take this occasion to return the kind courtesies extended to them and wish the Institution of Petroleum Technologists all success and prosperity. They are pledged to endeavour to make the Congress a success, with the sympathetic support of the Institution of Petroleum Technologists, and thereby contribute to the progress of engineering science and the enhancement of human welfare.

The World Engineering Congress.
Baron K. Furuichi, *President.*

Tokyo. *October 29th*, 1929.

BOOKS RECEIVED.

REPORT OF THE FUEL RESEARCH BOARD FOR THE YEAR ENDED 31ST MARCH, 1929. London: H.M. Stationery Office. Pp. viii. + 122, with 13 figures and 5 plates. 2s. net, postage extra.

This report summarises the progress for the period under review, but a more complete account is given in the Report of the Director of Fuel Research, which is incorporated. The subjects dealt with include the examination of coal, the effect of coal grading on carbonisation, the heating of retorts, low-temperature carbonisation, internal-combustion engines, hydrogenation, and gas sampling. This report should be of great value to those interested in up-to-date developments in the utilisation and carbonisation of coal.

THERMOELECTRIC TEMPERATURE SCALES. Wm. F. Roeser, U.S. Bureau of Standards Research Paper No. 99. U.S. Govt. Printing Office, Washington, D.C. 5 cents.

The International Temperature Scale adopted in 1927 is the fourth used by the Bureau of Standards since 1912. The purpose of the present work is to determine the change caused in the temperature scale, and to make available comparisons of the various scales. The methods used in realising the International Temperature Scale in the range 660° to 1063° C. are described in detail.

ERRATA.

We are informed by Mr. C. I. Kelly that, in his paper on Carbon Residue, *J. Inst. Petr. Techn.*, 1929, **15**, 76, he has inadvertently reversed certain figures in Table 5, page 508. The column headed "Variation in result per 1° C." should read: A., 0·00506; K., 0·00786; L., 0·0108; M., 0·0117; E., 0·0165; F., 0·031.

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